EXPLORING THE EFFECTS OF

INTERNATIONAL TRAFFIC IN ARMS REGULATIONS RESTRICTIONS

ON INNOVATION IN THE U.S. SPACE INDUSTRIAL BASE

THESIS

Kalliroi L. Landry, Major, USAF

AFIT/GRD/ENV/10-S01

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

EXPLORING THE EFFECTS OF INTERNATIONAL TRAFFIC IN ARMS REGULATIONS RESTRICTIONS ON INNOVATION IN THE U.S. SPACE INDUSTRIAL BASE

THESIS

Presented to the Faculty

Department of Systems and Engineering and Management

Graduate School of Engineering and Management

Air Force Institute of Technology

Air University

Air Education and Training Command

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Research and Development Management

Kalliroi L. Landry

Major, USAF

August 2010

EXPLORING THE EFFECTS OF

INTERNATIONAL TRAFFIC IN ARMS REGULATIONS RESTRICTIONS

ON INNOVATION IN THE U.S. SPACE INDUSTRIAL BASE

Kalliroi L. Landry, BS, MS
Major, USAF

Approved:

____________________________________ ____________________
J. Robert Wirthlin, PhD, Lt Col, USAF (Chairman) Date

____________________________________ ____________________
Alfred E. Thal, Jr., PhD (Member) Date

____________________________________ ____________________
R. David Fass, PhD, Lt Col, USAF (Member) Date

Abstract

The International Traffic in Arms Regulations (ITAR) are used to protect United States (U.S.) military technologies. However, changes to ITAR export controls regarding space technologies have had a major impact to the U.S. space industry. The literature mentions a concern for the health of lower-tier firms because they are a major source of innovation, but there is no additional information considering the effects of ITAR on space innovation at those lower tiers. The purpose of this thesis was to explore the implications of continuing the current ITAR restrictions with regard to innovation in the space industry. This research used a three-part approach: Part I used personal interviews to explore perceptions from the space enterprise. Part II was a secondary analysis of previously collected data. Part III compared the results of Parts I and II to assess the relationship between ITAR and innovation in the space industry. The analysis shows there is no significant evidence that ITAR has a direct effect on space innovation. However, the industry may see some secondary negative effects on innovation. This thesis reveals a need to examine other second or third order effects of ITAR in economic and political environments to advise current ITAR reform efforts.

To my son

Acknowledgements

Above all, I would like to thank God for granting me the gifts necessary to complete this educational milestone.

My most sincere appreciation goes to my thesis advisor, Lt Col Rob Wirthlin, for his expert guidance, remarkable patience, and enduring support and encouragement throughout my research effort.

I would also like to express my gratitude to my committee members, Dr Al Thal and Lt Col David Fass, as well as the other faculty members in whose classes I participated, for the wisdom they shared to make my AFIT education so rewarding.

A very special thank you goes to Mr Alan Taylor of the Air Force Research Laboratory and Mr Jason Bolton of the Department of Commerce who so graciously provided a significant portion of the data used in this research.

I am also very grateful to Mr Bob Boulware and the rest of my SAF/AQXA coworkers for their support and good-natured teasing during the final stretch of this effort.

Finally, I would like to thank my husband who, whether near or far, provided loving support and excellent proofreading skills.

Table of Contents

Page

ABSTRACT IV

LIST OF FIGURES IX

LIST OF TABLES IX

LIST OF ACRONYMS X

I. INTRODUCTION 1

BACKGROUND ON ITAR AND SPACE 2
IMPORTANCE OF THE INDUSTRIAL BASE 4
SPACE INDUSTRIAL BASE 5
PROBLEM AND PURPOSE STATEMENT 6
SUMMARY 7

II. LITERATURE REVIEW 8

POLICY 8
COMMISSIONED STUDIES 10
ARTICLES AND EDITORIALS 14
INNOVATION 17
Defining Innovation. 17
Measuring Innovation. 18
GAP IN LITERATURE 24

III. METHODOLOGY 25

OVERALL RESEARCH FRAMEWORK 25
PART I: PERCEPTIONS FROM THE SPACE ENTERPRISE 26
Interviews. 26
Sampling method. 28
Qualitative data coding. 30
PART II: SPACE INNOVATION SURVEY ANALYSIS 30
Data source. 30
Analysis. 33
PART III: COMPARISON ANALYSIS 33
SUMMARY 34

IV. RESULTS AND ANALYSIS 35

PERCEPTIONS FROM THE SPACE ENTERPRISE 35
Effects of ITAR on Innovation in the Space Industry. 36
Evolution of the Space Industry with Current Export Control System. 40
Recommendations to Improve Innovation in the Space Industry. 42
Additional Insights for Innovation in the Space Industry. 45
SPACE INNOVATION SURVEY ANALYSIS 49

Page

Context for foreign competition and export controls. *49*
Indicators of innovation. *54*
COMPARISON ANALYSIS 59
SUMMARY 61

V. CONCLUSIONS AND RECOMMENDATIONS 63

RESEARCH CONCLUSIONS 63
Research Questions. *63*
Strength of Innovation Measures. *65*
RECOMMENDATIONS 67
LIMITATIONS OF THE RESEARCH 68
FUTURE RESEARCH 69
SUMMARY 70

APPENDIX A: INTERVIEW INSTRUMENT 72

APPENDIX B: SELECTIONS FROM BIS 2006 SURVEY INSTRUMENT 73

REFERENCES 77

List of Figures

Page

Figure 1: Overall Research Framework 26

List of Tables

Table 1: Conflicts between ITAR and U.S. National Space Policy 13
Table 2: Measures of Innovation... 19
Table 3: Effects of ITAR on Innovation in the Space Industry.. 36
Table 4: Evolution of the Space Industry with Current Export Control System 41
Table 5: Recommendations to Improve Innovation in the Space Industry 43
Table 6: Additional Insights for Innovation in the Space Industry 45
Table 7: Top Five Reasons for Foreign Sourcing... 50
Table 8: Top Five Factors for Competitive Foreign Products.. 51
Table 9: Past Actions (Last Five Years) to Improve Competitiveness... 52
Table 10: Future Plans (Next Five Years) to Improve Competitiveness...................................... 52
Table 11: Suggested U.S. Government Actions to Improve Competitiveness............................. 53
Table 12: Barriers to Entry in Foreign Countries.. 54
Table 13: Space Related Foreign and Domestic Sales 56
Table 14: Space R&D Expenditures by Year.. 57
Table 15: Space R&D Expenditures by Tier 58
Table 16: Funding Sources... 58
Table 17: R&D Expenditures as % of Total Space Sales.. 59

List of Acronyms

AFRL	Air Force Research Laboratory
AIAA	American Institute of Aeronautics and Astronautics
BIS	Bureau of Industry and Security
CCL	Commerce Control List
CoCom	Coordinating Committee for Multilateral Export Controls
CSIS	Center for Strategic and International Studies
DoC	Department of Commerce
DoD	Department of Defense
DoS	Department of State
DUSD-IP	Deputy Under Secretary of Defense for Industrial Policy
EADS	European Aeronautic Defence and Space Company
ESA	European Space Agency
IP	Intellectual Property
IRAD	Independent Research and Development
ITAR	International Traffic in Arms Regulations
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NESDIS	National Environmental Satellite, Data, and Information Service
NOAA	National Oceanic and Atmospheric Administration
NSP	National Space Policy
NSSO	National Security Space Office

PP&E	Property, Plant, and Equipment
PRC	People's Republic of China
R&D	Research and Development
SBIR	Small Business Innovation Research
SIA	Satellite Industry Association
SIB	Space Industrial Base
STEM	Science, Technology, Engineering, and Mathematics
TAA	Technical Assistance Agreement
UN	United Nations
U.S.	United States
USML	United States Munitions List

EXPLORING THE EFFECTS OF

INTERNATIONAL TRAFFIC IN ARMS REGULATIONS RESTRICTIONS

ON INNOVATION IN THE U.S. SPACE INDUSTRIAL BASE

I. Introduction

The motivation for this research stems from a desire to understand how the U.S. manages its National Security Space Enterprise. Personal observations from the Schriever V Wargame of 2009 discovered some concerns with the policies, doctrine, and laws our space leaders use to manage the enterprise. Early discussions revealed that the topic is extremely complex and existing guidance documents are intentionally vague. However, many of these discussions also included complaints about the International Traffic in Arms Regulations (ITAR). These complaints led to the general question – How does ITAR affect space?

The U.S. Government established ITAR to protect U.S. military technologies. The current implementation of ITAR in the case of space technologies is hampering the growth of the U.S. space industry in the global market. The U.S. maintains a lead in space technology, but space innovation outside the U.S. has increased. Foreign companies are now developing *ITAR-free* satellites, signaling a decreasing dependence on U.S. technology. The purpose of this thesis is to explore the implications of continuing the ITAR restrictions that may be detrimental to U.S. space capabilities. If

ITAR has a negative effect on U.S. space innovation, future U.S. space solutions may not be superior to foreign technologies. With less superior solutions available to meet future requirements, the U.S. risks losing its long-standing space superiority. The U.S. must continue to foster space innovation to enable U.S. companies to compete in the global space market.

Background on ITAR and Space

Congress first implemented the International Traffic in Arms Regulations in 1976 under the Arms Export Control Act, found in Title 22, Chapter I of the Code of Federal Regulations, Sections 120 through 130. The purpose of ITAR is to prevent sensitive technology from reaching parties hostile to the U.S. As stated in ITAR, Executive Order 11958 delegated authority to the Department of State to regulate the export and import of defense articles and defense services (U.S. Congress 2009) which may include hardware, technologies, and services. The Department of Defense (DoD) captures and manages these items in the U.S. Munitions List (USML). Furthermore, two categories in the USML compose nearly all applicable material for space, Category IV – Launch Vehicles and Category VIII – Spacecraft (U.S. Congress 2009). When first enacted, this collection of regulations was extremely important to protect military technology, especially space technology, from leaking out of the country to hostile governments such as our Cold War rival, the Soviet Union. ITAR protected all military space systems because each system was unique to the mission for which it was designed.

With the conclusion of the Cold War, the U.S. began to look more at international space ventures. To that end, in 1988, President Ronald Reagan "lifted the ban on the use

of Chinese launch vehicles for commercial satellites" and President George HW Bush "made a similar decision with regard to Russia." In line with the Presidents' willingness to trade with the two rivals and increasing openness to international space ventures, in 1992 "the State Department transferred jurisdiction of some commercial communications satellites to the Department of Commerce" (Space Foundation 2008). By 1996, commercial communications satellites were fully transferred "under the purview of Commerce's less restrictive [Commerce Control List] CCL" (Taylor 2007). However, it should be noted that "the State Department continued to control the related communications technologies and the rest of the space items on the USML remained under its jurisdiction" (Space Foundation 2008). By taking such an action, the U.S. government was working to reduce the limitation of ITAR on exporting technology by attempting to separate non-military space technology from military.

In 1995 and 1996, investigations of two failed launches using the People's Republic of China's (PRC) lift vehicles to carry U.S. commercial satellites led to a breach of ITAR as discovered by the Cox Commission in 1996. Below is a summary of the incident and the commission's findings:

> Following the catastrophic launch failure of a Chinese Long March 3B rocket carrying the U.S.-built Intelsat 708 satellite, an Independent Review Committee composed of Loral and Hughes Space & Communications engineers met with PRC engineers to review the failure analysis performed by the Chinese. The Independent Review Committee took issue with the findings of the report, and therefore issued their own Preliminary Report, documenting two other potential failure points and recommending further testing.
>
> According to the U.S. Department of Defense (DOD), evidence suggests that the Independent Review Committee very likely led the PRC to discover the true source of failure of the rocket. The DOD also concluded that "Loral and Hughes committed a serious export control violation by virtue of having performed a defense service without a license…" (U.S. House of Representatives 1999)

Because of the commission’s findings, the companies involved were fined a total of 65 million dollars. Furthermore, the Department of Commerce returned jurisdiction to the Department of State as “all satellites and satellite technologies were once again placed on the USML and exports were governed by ITAR” (Space Foundation 2008). Since this transition of jurisdiction, the government has not significantly altered ITAR in terms of space technology.

Importance of the Industrial Base

Several studies have researched the effects of ITAR on the U.S. industrial base because the DoD holds a strong interest in understanding the state of the defense industrial base. This resource is vital to maintain the ability to produce military capabilities and provide surge support when needed. Evidence of the importance the DoD places on the Defense Industrial Base is seen in examples such as the Office of the Deputy Under Secretary of Defense for Industrial Policy (DUSD-IP), the Annual Industrial Capabilities Report submitted by DoD to Congress, the Defense Contract Management Agency’s Industrial Analysis Center, and established councils at the joint level and service level. All of these examples have the primary goal of maintaining awareness of issues affecting the industrial base so that the DoD may leverage the industrial base effectively to meet warfighter needs. The councils and reports study and address issues such as globalization; manufacturing and engineering expertise; eroding U.S. leadership in science, technology, and engineering; the aging workforce; and DoD policies and requirements.

Space Industrial Base

The U.S. continues to lead the world in space technology development, but the current domestic demand is not sufficient to sustain the U.S. space industry (AFRL 2009). Access to the global space market will result in growth for the U.S. space industry. However, any transaction with a foreign country involving space technology requires ITAR approval. This is typically not a problem for large companies with established export programs. There is, however, a greater impact to small firms due to the resources required for registration and maintaining a compliance infrastructure. Because smaller companies are considered to be a major source of innovation (Space Foundation 2008), the combination of barriers to their participation in the global market and the low domestic demand for space technologies may result in less opportunities for space innovation in the U.S. This could lead to the conclusion that ITAR is stifling U.S. space innovation. While space innovation may be suffering in the U.S., space innovation is increasing overseas, and the U.S.'s dominance in space technology may be losing its edge. Companies outside the U.S. are now developing technologies and components traditionally supplied by the U.S., thus creating more competition. ITAR raises barriers for competition in the global space market. One reason for barriers raised by ITAR is that the export license process takes too long. Foreign governments are able to take advantage of these barriers to keep economic benefits within their own nations. For example, they may intentionally set shorter deadlines for contract proposals which they know U.S. companies will not be able to meet due to the lengthy ITAR licensing process (Space Foundation 2008).

Problem and Purpose Statement

Since 1999, when all space technologies returned to the protection of ITAR, several published articles and studies address the effects of those international restrictions on the U.S. Space Industrial Base (SIB). Statements and comments refer to a concern for lower-tier firms because they are a major source of innovation. The literature, as reviewed in Chapter II, provides no additional information considering the effects of ITAR on space innovation at lower tiers. Therefore, this research investigates the following questions:

1. What are the effects of ITAR restrictions on innovation in the U.S. SIB?
2. Are there any indications that innovation in the SIB is declining since stricter ITAR restrictions were imposed in 1999? If so, what are they?
3. What is the perception of the health of innovation in the SIB from space leaders in government and industry?

This research explores the connection between ITAR and its effects on space innovation. This study does not detail various flaws of ITAR or recommend changes to existing export policies; however, it considers potential unintended consequences or second-order effects of ITAR with a focus on innovation in the U.S. space industry.

Methodology

This study evaluates the research questions using a combination of qualitative and quantitative analysis. The overall framework includes three parts (1) data collection through interviews of government and industry representatives, (2) a secondary analysis of existing data, from a 2007 space industrial base survey by the Department of

Commerce, and (3) a comparison analysis between the interviews and the existing data. The methods used include data coding and theme development for interviews and secondary analysis of data from the survey.

Summary

This chapter introduced the topic of this thesis with background information on ITAR and its connection to the space industry, a summary of the importance of the industrial base, and a look at the space industrial base. Chapter II presents an in depth literature review of national policies relevant to space and export controls, commissioned studies along with articles and editorials looking at ITAR and the space industrial base, and relevant innovation concepts. Chapter III provides a detailed description of the research methodology that covers a three-part framework, including data collection through interviews, a secondary analysis of existing data, and a comparison analysis between the interviews and the existing data. Chapter IV presents the results of the data analysis. Finally, Chapter V provides conclusions and outlines recommendations for further research.

II. Literature Review

This chapter presents the relevant supporting information for this research found in existing literature based on four sub-topics: Policy, Commissioned Studies, Articles and Editorials, and Innovation. The final paragraphs outline the gap in the literature on which this research focuses.

Policy

The United Nations (UN), realizing the great prospects of space exploration for mankind, drafted a treaty in 1967, commonly referred to as the Outer Space Treaty, to ensure that the exploration and use of outer space would be for peaceful purposes and for the benefit of all people and countries irrespective of their economic or scientific development (United Nations 1967). The treaty also encourages international cooperation for scientific investigation in outer space. The development of technologies to explore and use space requires significant investment of financial and intellectual capital. Only a few governments committed to this investment at the beginning of the space race. However, additional nations (not as economically developed) have become players in the space business by forming consortia to combine their limited resources and benefit from the continuously increasing prospects of space.

The U.S. established the National Space Policy (NSP) in 1978 and periodically updates it as political and economic climates change. The release date of the most recent version of the NSP is June 28, 2010; however, this research references the 2006 version

(National Space Policy 2006). The NSP continuously aligns with the United Nations' treaties and principles on outer space. Moreover, the NSP outlines additional principles to strengthen and secure the nation's space leadership. One of the guiding principles found in this policy states that the U.S. "is committed to encouraging and facilitating a growing and entrepreneurial U.S. commercial space sector" (National Space Policy 2006). This statement recognizes the need to encourage space innovation as a significant contribution to the U.S. economy. Furthermore, specific fundamental goals in the NSP emphasize the U.S. desire to remain a major player in space. The first goal relates to the need to maintain the U.S. space industrial base to "ensure that space capabilities are available in time to further U.S. national security…" Another goal is to "Enable a dynamic, globally competitive domestic commercial space sector in order to promote innovation, strengthen U.S. leadership, and protect national, homeland, and economic security…" This goal directly recognizes the connection between innovation and global competitiveness. In addition, the NSP acknowledges the importance of international cooperation "on space activities that are of mutual benefit and that further the peaceful exploration and use of space…"

Finally, the NSP specifically recognizes a need for effective export policies. This concept is crucial to supporting the fundamental goals of the NSP relating to innovation and international cooperation. When reviewing export license requests, "space-related exports that are currently available or are planned to be available in the global marketplace shall be considered favorably." However, since the U.S. considers space capabilities to be vital to its national interest, exports of "sensitive or advanced technical data, systems, technologies, and components, shall be approved only rarely…" (National

Space Policy 2006). This statement illustrates the need for the U.S. to balance national security with economic security to remain a global space leader.

Commissioned Studies

From 2007 through 2009, there have been at least eight studies that examined the health of the U.S. industrial base in general and the effects of ITAR specifically on the SIB. Key findings agree across these studies with regard to the space industry. Large defense contractors in the SIB are healthy, but there is some concern for key lower-tier suppliers (CSIS 2008; AFRL 2009). AFRL's 2009 Industrial Base Assessment points out that demand for global commercial and domestic military space systems is strong through at least 2012 (AFRL 2009). Upgrade and replacement efforts for nearly all on-orbit assets currently under-way in the national security space sector contribute to the "good" financial health of top-tier manufacturers in the SIB (CSIS 2008). However, export control requirements present a significant barrier to competing in foreign markets while there is an insufficient domestic demand to keep all suppliers operating at efficient capacity (AFRL 2009). Abbey and Lane (2009) show there is a direct correlation between export policies, cost of compliance, and financial health of smaller suppliers. Furthermore, domestic sources are diminishing or are at-risk for key items such as solar arrays and radiation-hardened electronics (AFRL 2009). U.S. space firms need to expand to the global community in order to survive.

The concern for key lower-tier suppliers directly relates to a concern for innovation in the SIB. The Space Foundation's 2008 study on ITAR and the U.S. space industry states that lower-tier companies are a major source of innovation. Lower-tier

companies invest a much higher percentage of internal funds as a percent of sales on space Research & Development (R&D) than larger aerospace contractors who rely more on government funding for research (Taylor 2007; NSSO 2008). Growth in R&D expenditures was seen primarily in lower-tier companies as an investment in innovation to remain competitive (Taylor 2007). However, the Institute for Defense Analyses' 2007 study mentions that U.S. commercial firms are reluctant to engage in R&D activities for the DoD because of potential Department of State restrictions (Van Atta et al. 2007). Another report states that ITAR discourages companies from supplying their best technologies to the DoD so that they can compete in commercial and international markets for potentially higher sales volume and profits (OUSD-ATL 2009).

All the space industry studies agree that ITAR inhibits the ability to compete or participate in the global space community (Taylor 2007; CSIS 2008; NSSO 2008; Space Foundation 2008; AFRL 2009). The uncertainty of ITAR processes and processing times impacts the space industry's confidence to compete in foreign markets (CSIS 2008). Lengthy processing times for license requests are a major cause for loss of foreign sales (Taylor 2007; Space Foundation 2008). Export control compliance costs are a significant burden for lower-tier firms (Taylor 2007; NSSO 2008; Space Foundation 2008). "As a percent of foreign sales, the cost burden on Tier 3 companies is nearly eight times that of Tier 1 firms" (CSIS 2008). Tier definitions are Tier 1 – prime contractors, Tier 2 – subcontractors, and Tier 3 – commodity suppliers (Taylor 2007). ITAR makes it difficult to hire the best talent and also inhibits access to foreign technology (NSSO 2008). The U.S. Munitions List (USML), which lists the products and services that ITAR protects, includes technologies that are already commercially available in other countries (NSSO

2008; Space Foundation 2008). Specifically, the USML classifies commercial communications satellites as “munitions.” As a result, satellite manufactures must adhere to ITAR licensing requirements when developing products that include any components also found on the protected communications satellites – these components may already be openly available outside the U.S.

In some cases, ITAR has encouraged the rise of foreign space capabilities. Foreign competitors take advantage of U.S. export controls (Taylor 2007; Space Foundation 2008; Abbey and Lane 2009; AFRL 2009). They may intentionally set shorter deadlines they know U.S. companies will not be able to meet due to the lengthy ITAR licensing process (Space Foundation 2008). In response to continued problems with U.S. trade restrictions, there is a growing *ITAR-free* movement where foreign companies are funding the development of satellite components typically acquired from the U.S. (CSIS 2008; Abbey and Lane 2009) – “they are choosing to avoid dealing with U.S. export controls by not using American-made parts” (Abbey and Lane 2009). This is evidence that the intent of space export controls – to prevent sensitive technology from reaching parties hostile to the U.S. – is not being achieved (CSIS 2008).

Because of increasing foreign competition in the space industry, the U.S. share of global space markets is steadily declining (Taylor 2007; CSIS 2008; AFRL 2009; Futron Corporation 2009). From 1999 to 2006, the U.S. share of satellite manufacturing for all communication satellites sales decreased 20% and for geosynchronous orbit communication satellites the decrease was 10% (Taylor 2007). A 2009 study sponsored by the Satellite Industry Association indicates that the U.S. share of manufacturing revenues fell from 41% to 29% of the world total from 2007 to 2008 (Futron Corporation

2009). This steady decline in the U.S. share of global space markets is most likely due to foreign companies choosing not to buy from the U.S. due to export controls and having U.S. components and technology designed out of satellite systems (CSIS 2008).

Finally, U.S. space export control policy is not in agreement with the national space policy (CSIS 2008). A study conducted by the Center for Strategic & International Studies shows specific examples where some elements of ITAR are in conflict with the goals of the NSP. Table 1 captures the findings. These findings further emphasize the idea that the U.S. is not achieving the strategic intent of space export controls and there is a continuing need to balance economic security with national security.

Table 1: Conflicts between ITAR and U.S. National Space Policy

Among the unintended consequences of ITAR:	**Corresponding section in U.S. National Space Policy:**
USML not consistent with current assessment of which space technologies should be controlled	"space-related exports that are currently available or are planned to be available in the global marketplace shall be considered favorably"
U.S. space export control regime does not match its goals of both enabling cooperation with allies and denial of capabilities to opponents. The current regime does not provide policy makers with the nuance or flexibility needed to serve the National Space Policy.	"Develop and deploy space capabilities that sustain U.S. advantage and support defense and intelligence transformation; … Develop capabilities, plans, and options to ensure freedom of action in space, and, if directed, deny such freedom of action to adversaries"
Satellites and their components placed on USML with intent to limit spread of space technology. Unintended consequences: encouraged proliferation of space capabilities; failed to prevent rise of other space powers; impacted U.S. competitiveness	"Refrain from conducting activities that preclude, deter, or compete with U.S. commercial space activities, unless required by national security or public safety"
Adverse industrial/technological impact to U.S. ITAR implementation introduces a friction for U.S. companies competing in the global market, as much as $600 million a year, which in turn feeds space development that the U.S. is not involved in	"A robust science, technology, and industrial base is critical for U.S. space capabilities… Use U.S. commercial space capabilities and services to the maximum practical extent"
The continuation of our legacy of beneficial collaboration with foreigners has been impeded, as has our ability to do anomaly resolution	"Encourage international cooperation … on space activities that are of mutual benefit and that further the peaceful exploration and use of space, as well as to advance national security, homeland security, and foreign policy objectives"

Source: Center for Strategic & International Studies, 2008

Articles and Editorials

Several articles are available that address the issue of ITAR in relation to the space industry. These articles primarily speak of the hardships companies in the U.S. space industry have faced since commercial satellites returned to the USML in 1999. Opinions are consistent across all the articles.

The main concern is that instead of protecting U.S. national security interests, the export policy has closed off a profitable export industry. "The result has been the deliberate development by overseas manufacturers of … devices and systems that are the equivalent of American technologies … not subject to ITAR" (Wheatley 2009). Even in the case of U.S. dual-use technologies, export restrictions do not have any impact on what other nations are able to sell (Dinerman 2005). Dinerman (2008) poses a relevant question: How does a superpower balance the needs of its national security system and its need to trade? The majority of the articles reiterate the fact that ITAR has negatively affected the U.S.'s participation in the global space market. Foust (2005) points out that since oversight of satellite technology exports was transferred to the State Department, "it has become far more difficult for U.S. companies to sell satellites and satellite components to customers outside the [U.S.], even to friendly nations such as Canada and Britain." Global competition has grown and U.S. companies are finding it difficult to compete with foreign companies offering *ITAR-free* satellites. Contractors around the globe have the option of acquiring equivalent technologies from companies outside the U.S. Wheatley (2009) provides two specific examples: (1) Canada has specifically cited ITAR as a reason for selecting European satellite builders and (2) EADS Sodern, a French company, is phasing out its American supplier base.

According to Congressman Brad Sherman (D-CA), even the intelligence community is finding it difficult to source satellite-related components domestically (Space Politics 2009). This leads the reader to question the superiority of U.S. space technologies and components when compared to what is available in the global market.

The most popular recommendation to remedy the frustrations of the U.S. space industry is to review and revise the USML to exclude technologies which are readily available as commercial-off-the-shelf technologies around the globe (Kusiolek 2008; Boucher 2009). Despite their widespread commercial availability, the USML classifies communications and other commercial satellites as “weapons systems” (Dinerman 2008). “Screws, lithium-ion batteries, simple rivets – if they have a defined space application, their export is banned, or subject to ITAR’s burdensome licensing applications and controls” (Wheatley 2009).

Another suggestion is to re-establish a multilateral Cold War organization called the Coordinating Committee for Multilateral Export Controls (CoCom) (Dinerman 2008; Knes 2010). The CoCom brought together 17 member states, including the U.S., its NATO allies, Japan, and Australia, in an informal setting where they could agree on what exports they would allow. “The organization’s extreme discretion and its lack of a formal legal structure insured that no nation could publicly lose face” (Dinerman 2008). The main point of Dinerman’s suggestion is to find a way for the U.S. to treat its close allies as trusted friends with regard to trade.

The lengthy and unpredictable ITAR process takes much of the blame for foreign contractors phasing out U.S. suppliers for satellites and satellite components. Pierre Chao, a senior associate at the Center for Strategic and International Studies, said that

interest in ITAR-free satellites is prompted "by the uncertainty embodied with the U.S. ITAR system" (Space Politics 2009). This uncertainty refers to delays in getting approvals for export licenses and related agreements. There is acknowledgement of some progress with the ITAR process. For example, the State Department is already starting to process export license applications more rapidly (Space Politics 2009) – requiring decisions to be made within 60 days of the application (Dinerman 2008).

The literature proposed several recommendations to fix this lengthy process. One recommendation considers a two-tier approach that would treat exports to allied countries in a more expeditious manner (Foust 2005). This would be a way to trade with close allies while treating them as trusted friends. Another recommendation is to allow space parts for systems that have already been exported to close allies to be shipped without having to go through the ITAR process (Dinerman 2008). In addition, there are complaints that the State Department must enhance the transparency of the export control process. This should include explanatory notes for USML categories as well as public release of the results of Commodity Jurisdiction requests (Boucher 2009). Still the cost of compliance weighs heavily on many U.S. firms, particularly small companies, resulting in reduced profit margins to cope with ITAR (Dinerman 2008).

Looking beyond commercial satellites, Foust (2005) raises concerns for ITAR's effect on the up-and-coming space tourism industry. With the uncertainty of possible licensing requirements, U.S. companies with designs for commercial space vehicles are unable to share their designs with foreign companies looking to venture into the space tourism business. Foust (2005) says a worst-case scenario would be that ITAR could restrict who could fly on future space-tourism vehicles. Companies may need to obtain a

license for every non-U.S. passenger because some technical information may need to be shared with passengers for safety reasons. This could make it difficult for U.S. companies to succeed, pushing the space tourism market overseas (Foust 2005).

Innovation

Defining Innovation.

The literature defines innovation in various ways. It is not simply the creation of a new idea. The Cambridge dictionary (2010) defines innovation as “(the use of) a new idea or method.” Chesbrough (2003) says it is an “invention implemented and taken to market.” Bessant and Tidd (2007) outline three core themes of innovation, which are generating new ideas, selecting the good ones, and implementing them. However, no discussion on innovation is complete without reference to Josef Schumpeter. In his 1934 publication, The Theory of Economic Development, Schumpeter (1934) defines economic innovation using five categories:

1. The introduction of a new good or of a new quality of a good
2. The introduction of a new method of production
3. The opening of a new market
4. Development of a new source of supply of raw materials
5. The new organization of an industry

Rogers (1998) refers to several authors to establish a definition for innovation as a foundation for measuring innovation. In addition to innovation describing something new or improved, Rogers (1998) refers to a survey used by the Australia Bureau of Statistics (1996) in which innovation is defined as “any new or substantially improved

good or service which has been commercialized, or any new or substantially improved process used for the commercial production of goods and services." The key in this definition is the commercialization of something new or improved. Rogers (1998) also emphasizes that new knowledge, products, or services are not innovation until they add value through the productive incorporation into an enterprise's activities. This idea is derived from the Business Council of Australia (1993) which defines innovation as "something that is new or significantly improved, done by an enterprise to create added value either directly for the enterprise or indirectly for its customers." Adding a timeframe to innovation, Rogers references a definition used by Phillips (1997) in which a firm is considered to be "innovative if it introduced at least one new or substantially improved product or process in a three year period." For the purpose of this paper, innovation is a new idea for a new or improved product or process, implemented within a three-year period, and adds value to an enterprise.

Measuring Innovation.

The concept of measuring innovation is important to empirically prove or test innovation management concepts. However, it has been difficult to find a record of well-established measures for innovation. A search of the literature reveals "a diversity of approaches, prescriptions and practices that can be confusing and contradictory" (Adams, Bessant, and Phelps 2006). Some articles refer to proxies that have been used in the past, but later articles point out flaws in using those proxies. Measuring innovation can be a challenge because of the broad nature of activities in the innovation process (Rogers 1998).

Typically, in measuring innovation, there is a distinction between inputs to innovation activity and outputs from innovation activity. Inputs relate to resources and include finance, human and physical resources, and the generation of new ideas (Adams et al. 2006). Outputs relate to measuring the success of a firm using econometric techniques or other variables resulting from innovative activities (Rogers 1998). Table 2 is a summary of measures and proxies used to measure innovation in a firm. The following paragraphs address these measures.

Table 2: Measures of Innovation

Input Measures	Output Measures
Expenditure for R&D	Firm performance
Intellectual Property Statistics/Acquisition of technology from others (e.g. patents, licenses)	Intellectual Property Statistics
Intangible assets (include goodwill and capitalized R&D)	Introduction of new/improved products/processes
Expenditure on tooling-up, industrial engineering, and manufacturing start-up associated with new products/processes	Percentage of sales from new/improved products/processes
Expenditure on marketing new products/processes	Market Share
Expenditure on training for new/changed products/processes	Strategic success: growth in market share over a period of time
Managerial and organizational change	

Sources: Rogers 1998, Tables 1 & 2; Bessant & Tidd 2007

Expenditures for R&D is the most frequently used proxy for the level of innovative effort in a firm. This is a well-understood figure using readily available dollar amounts. It is typically expressed as a ratio between expenditure and some expression of output (Adams et al. 2006) or as a ratio of R&D to value added (Tidd 2001). Some examples include total expenditure, expenditure as a proportion of sales or revenues, and expenditure by item (patent, organizational department, innovation or scientist) (Adams

et al. 2006). Rogers (1998) points out that there may be issues with using R&D as a proxy for innovation because of varying definitions of R&D. His concern is that the definition for R&D may be too general, "the outcome of which is new knowledge, with or without a specific practical application," and does not coincide with the definition for innovation, which would require some practical application. However, he suggests that commercial firms would aim R&D at creating innovations for commercial exploitation. Tidd (2001) suggests that R&D activities have a significant positive effect on the number of new products introduced as well as value added, which can be considered output measures of innovation.

Adams, Bessant, and Phelps raise other concerns for using R&D as a proxy for innovation in their 2006 review of innovation management measurement. First, they argue that R&D is not an adequate proxy because it is only one of several inputs into the innovation process. They also argue that, even though adequate funding is a critical input into the innovation process, high levels of R&D funding may not be evidence of good innovation because they may mask process inefficiencies. Another concern these authors have is that small and medium-sized enterprises, as well as service industries, do not have formal R&D activities, in which case, R&D would not be an effective measure.

Knowledge management is also an important aspect of innovation. "Ideas are the raw materials for innovation" (Adams et al. 2006). Assessing the value of a firm's intellectual property (IP) is a way to measure its accumulated knowledge. Intellectual property can be either an input or an output to the innovation process. It is considered an output because the process of applying for IP rights implies that a company has created some new knowledge that needs to be protected (Rogers 1998). As outlined by Rogers

(1998), IP includes patents, trademarks, design data, and the value of intangible assets. He defines intangible assets to be “an overall valuation for goodwill, capitalised past R&D, as well as valuations of any holdings of patents, trademarks and licenses” (Rogers 1998). Bessant and Tidd (2007) also include scientific papers in the list of IP. Counting the numbers or values of patents is the most frequently used approach and has been widely accepted as a proxy measure for innovation (Adams et al. 2006). The number of applications for patents can be a proxy for innovation output, because it represents a new idea to the firm even though another firm may have already registered the idea (Rogers 1998). Counting the number of patents granted may compensate for the weaknesses of R&D statistics (Tidd 2001).

Rogers (1998) explains that using patents as a measure can be a problem for two reasons. First, the existence of a patent does not necessarily mean the idea was used commercially. Second, not all ideas can or will be patented, either for legal reasons or to prevent competitors from using this knowledge to their advantage. The acquisition of technology from others in the form of patents or licenses can be an input measure. There is limited study on the use of trademarks and design data as indicators of innovation; trademarks usually group together with patents. The value of intangible assets can be used as a measure of past innovation while the change in intangible assets between two periods can be used as a proxy for current innovation effort (Rogers 1998).

Rogers (1998) also addresses additional inputs to consider when measuring innovation in a firm. In many cases, new products or processes may require additional expenditures for tooling-up, industrial engineering, and manufacturing. Inputs to innovation also include marketing and training expenditures associated with new

products. These inputs are crucial to innovation because of their contribution to developing and extracting value from new ideas. Lastly, changes to a firm's managerial methods and organizational structure may be an input to innovation. This is difficult to measure and has typically been a yes-no response in survey questions that ask if there have been such changes (Rogers 1998).

Several options are available for measuring the outputs of innovation. Intellectual property is one measure mentioned earlier. In addition, Bessant and Tidd (2007) offer three groups of output measures. First, a firm can measure operational or process elements through customer satisfaction surveys to indicate improvements in quality or flexibility. Next, some output measures, such as cost of product, market share, and quality performance, can be compared across sectors or enterprises. Last, measures of strategic success, including growth in revenue or market share and improved profitability, can in part be attributed directly or indirectly to innovation.

Rogers (1998) describes how outputs can be measured by the number of new or improved products or processes introduced by a firm or by the percentage of sales from those new or improved products or processes. Counting the number of new or improved products is only a "crude" indicator of a firm's level of innovation. Estimating this information as a percentage of sales accounted for by new products, improved products, and unchanged products refines the measure as an assessment of past innovation. The expectation is that highly innovative firms would have a higher percentage of sales from new and improved products.

The key output measure of innovation is the success of a firm. Proxies to measure firm success include profits, revenue growth, share performance, market capitalization,

and productivity (Rogers 1998). Many of the measures mentioned earlier are only partial measures of a firm's overall innovation ability. Using econometric techniques to relate the various innovation measures to the overall performance of a firm can correct for this. This is most commonly done with R&D data, using market value and productivity to quantify firm success (Rogers 1998).

The space industry thrives on the expectation of continuous technology advancements, thus depending on a substantial level of innovation. For the purpose of this research, the innovation measures described above are most applicable to technology development. These are R&D expenditures, IP, the number of new products introduced, percentage of sales or profits from new products, U.S. market share of the space industry, and global market share data over several years.

R&D expenditures are an appropriate measure because many developments for the space industry tend to be unique to meet specific customer needs or mission requirements. However, this research will consider other measures of innovation along with R&D expenditures in consideration of the concerns expressed above. Intellectual property is also an appropriate measure. Realizing that not all firms have the same level of importance for IP, for those that make IP a priority, this measure will be a good indication of innovative activities. The number of new products introduced along with the percentage of sales or profits from new products would be good measures for some firms in the space industry due to the uniqueness of mission requirements – these firms would introduce more products that are new. However, for those firms that provide standard components not requiring unique developments, it is unlikely that data on new products introduced will be as prevalent. Finally, since the purpose is to explore the

effects of ITAR export policy on innovation, this research considers the U.S. market share of the space industry in relation to the rest of the world, rather than looking at individual firms. Reviewing global market share data over a period of several years may provide a partial indication of continued innovation activities in the U.S. space industry.

Gap in Literature

Several SIB studies express a concern for lower-tier firms because they are a major source of innovation. However, there is no additional information considering the effects of ITAR on space innovation at those lower tiers. The studies have done a thorough job in describing the difficulties faced by many firms in the U.S. SIB. These difficulties include a lengthy licensing process, cost of ITAR compliance, and generally, the ability to compete in the global space market. The articles and editorials further enumerate the shortcomings of ITAR and complaints from industry on the U.S.'s ability to balance national security with economic security. However, there is no further mention of the effects on innovation. This research does not intend to detail various flaws of ITAR, but to explore how some unintended consequences of ITAR may be affecting innovation in the U.S. Space Industrial Base.

III. Methodology

This chapter provides a description of the methodology for this research that includes both qualitative and quantitative components.

Overall Research Framework

The overall approach used for this study, illustrated in Figure 1, combines qualitative and quantitative elements. The literature review for this research investigated key concepts and existing studies regarding ITAR and the U.S. space industrial base as well as indicators of innovation. This effort, combined with personal experience in Air Force space acquisition, suggested some focus areas for the current research and helped to form the research questions. The main area requiring further understanding was the link between ITAR and innovation in the U.S. space industry, of which there appears to be no additional documented discussion. As a result, an initial exploratory study provided insight into and comprehension of the proposed link between ITAR and space innovation. This led to the development of a three-part approach: Part I used personal interviews to explore perceptions from the space enterprise, Part II was a secondary analysis of previously collected data, and Part III compared the results of Parts I and II to develop conclusions about the relationship between ITAR and innovation in the space industry. Using derivative data for Part II poses some concern with the danger of incorrectly interpreting the information collected for a different purpose. However, the

exploratory nature of this research allows for the use of derivative data to provide insight into the situation, rather than provide definitive conclusions.

Figure 1: Overall Research Framework

Part I: Perceptions from the Space Enterprise

Interviews.

The first portion of this research gathered information regarding key themes representing perspectives from various participants in the U.S. space industry, including small business representatives and senior government space leaders. Data was gathered through interviews, using a set of specific questions to maintain the appropriate context for the interviews. However, respondents had the opportunity to discuss their thoughts in an open-ended format in order to allow for the inclusion of additional relevant information that not specifically requested. Interviews were conducted by telephone and in-person as opportunities allowed. The following questions applied to all respondents:

1. How do you or your business participate in the Space Industrial Base?

2. What are your perceptions of the effects of ITAR on innovation in the space industry?

3. How do you expect the U.S. space industry will evolve with the current system of export control policy?

4. What other factors do you think affect innovation in the space industry?

5. If you were king/queen for a day, what would you change?

6. Do you have any additional comments regarding ITAR and the space industry?

When speaking with industry representatives, interviews included the following questions:

7. What are your perceptions of your business's innovation capability for space technology?

    a. Since 1999, for how many patents has your business applied? Been granted?
    b. Since 1999, how many technical papers have members in your business published?
    c. Since 1999, how many new ideas/products has your business introduced into the space market?
    d. Since 1999, on average, what was your percent of sales/profits from new products?

8. What are your perceptions of the effects of ITAR on your business's innovation capability for space technology?

The goal of formulating these questions was to solicit the respondents' perceptions of how ITAR and innovation in the space industry may be related. The information gathered from the literature review was the basis for developing the interview questions. The survey questions used for Part II of this research were not available until after the interview questions were developed. The consolidated interview instrument is included in Appendix A.

Sampling method.

The target population for this research was any individual or group that participates in the U.S. space industry through some kind of interaction with ITAR. This range of participation includes government agencies and organizations for policy formulation and implementation, government customers of the space industry, and individuals and firms in the space industry that are subject to ITAR in their businesses. The National Security Space Office (NSSO) provided guidance in selecting interview subjects for this research. Because the NSSO collaborates across the defense, intelligence, civil, and commercial communities, the office is in a unique position to bring together senior government officials and invited guests for the Space Industrial Base Council to facilitate communication with industry leaders. Also, the NSSO is committed to providing expert products and advice for space industrial base development and assessing programs across National Security Space, DoD, the Intelligence Community, and civil, commercial, and international space (NSSO 2010). The NSSO's focus on cross-space enterprise issues ensured consideration of the entire target population.

Sampling of the space industry focused on second- and third-tier firms because these levels of industry are a primary source of innovation. Industry participants were randomly selected from a list of lower-tier firms used in the NSSO 2008 study, "Barriers to Entry and Sustainability in the U.S. Space Industry." Purposive sampling was the method used to select government participants based on recommendations from the NSSO to guarantee representation from the appropriate government agencies because of the need for a specialized population (Neuman 2006; Trochim & Donnelly 2008).

Snowball sampling allowed a more comprehensive representation of the network of people or organizations involved in ITAR and space issues (Neuman 2006; Trochim & Donnelly 2008). The following organizations participated in this study:

- American Institute of Aeronautics and Astronautics (AIAA)
- Bureau of Industry and Security, U.S. Department of Commerce
- Commercial Remote Sensing Regulatory Affairs Office, National Oceanic and Atmospheric Administration (NOAA)
- Defense Technology Security Administration, Office of the Under Secretary of Defense for Policy
- Directorate of Defense Trade Controls, U.S. Department of State
- National Environmental Satellite, Data, and Information Service (NESDIS), NOAA
- National Security Space Office
- Office of Space Commercialization, NOAA
- Space & Missile Systems Center, Air Force Space Command

The above list does not include the National Aeronautics and Space Administration (NASA) because, generally, ITAR allows for treatment that is more permissive for U.S. Government agencies. NASA is able to apply several exemptions listed in ITAR. The procedural requirements document for the NASA Export Control Program (NASA 2007) includes a chapter which specifically addresses ITAR procedures. The chapter lists eleven exemptions from ITAR that are relevant to NASA activities. One specific example refers to Section 126.4 of the ITAR, which refers to shipments by or for U.S. Government agencies. Paragraph (a) of this section allows for

the temporary export of any defense articles by or for any U.S. government agency for official use by that agency, or for carrying out foreign assistance or cooperative projects (U.S. Congress 2009). ITAR does not restrict NASA as much as it does companies in the commercial industry.

This research contains 17 interviews. Seven of these represent lower-tier firms, while the remaining ten represent government or other space organizations.

Qualitative data coding.

Content analysis was the method used for analyzing the data collected through interviews by transcribing and organizing the raw responses into conceptual categories using thematic analysis (Trochim & Donnelly 2008). The analysis used latent coding (Neuman 2006) to extract key themes from the interviews and develop an overall understanding of the existing perceptions of the state of innovation in the U.S. space industry. This coding enabled recognition of similar evidence in the quantitative data. Chapter IV contains the categories and combined data.

Part II: Space Innovation Survey Analysis

The intent of the second portion of this research was to obtain quantitative information based on relevant industry data. This was accomplished through an analysis of data previously collected from the U.S. space industry with a focus on indicators of innovation in the U.S. space industry from 2003 to 2006.

Data source.

The Department of Commerce’s Bureau of Industry and Security (BIS) collected the survey data used for this research. In 2006, BIS, in coordination with the U.S. Air

Force, the NSSO, NOAA, NASA and others, conducted a survey of the U.S. space industry. The purpose of the survey was to analyze the health and competitiveness of the space industry. Relevant to the current research, the BIS included an analysis of the effects of foreign competition and export controls on the industry's ability to meet defense and commercial market demands. The survey had a 74% response rate with inputs received and verified from 202 space industry companies/business units. Respondents were characterized using tier levels where prime contractors were Tier 1, subcontractors were Tier 2, and commodity suppliers were Tier 3. Tier 1 includes companies that sell end-products to commercial or government customers in their fields. Examples include companies selling satellites, launches, or satellite services. This group includes emerging launch companies who are developing launch vehicles and services. Companies in Tier 2 provide major components and/or systems to Tier 1 companies. Components provided are complex and are significant parts of the end-product. Examples of products made by Tier 2 companies include satellite antennas and solid rocket boosters. Tier 3 companies provide less complex components, sub assemblies, structures, and materials. These companies also provide engineering, information technology, research, and custom fabrication services. A breakout of companies by sector (i.e. launch services, satellite manufacturing, etc.) could provide some additional insights to understand the health of the space industry; however, this is not the case for this research because many respondent companies contributed to more than a single space industry segment. Where appropriate, respondents provided data for each year from 2003 to 2006 along with estimates for 2007.

In reviewing the BIS survey instrument, six survey items were selected which were best aligned with the indicators of innovation described in Chapter II or provided some context relating to foreign competition and export controls in the space industry. The selected survey items are included in Appendix B. BIS provided the data for these items categorized according to the tier levels. All other identifiable names or references were removed to protect the anonymity of the respondents. The tier-level categorization is necessary for the current research because of the previously stated need to focus on lower-tier firms. Specific survey items relating to indicators of innovation are #5-Space-Related Defense & Non-Defense Sales, #20-Financials – Balance Sheet, and #22-Research and Development. Item #5 provided both domestic and foreign sales information for each year. Item #20 specifically included a line requesting an annual value for "Intangibles" which refers to patents, trademarks, and goodwill. Item #22 requested expenditure values for basic research, applied research, and product development, as well as amounts from funding sources such as internal, federal government, state or local government, U.S. private entity (industry, universities, and other non-governmental organizations), or foreign investors. The data from this item is an indicator of a firm's investment in innovation, as per Chapter II.

The survey items providing contextual information are #8-Reasons for Foreign Sourcing, #11-Foreign Competitors, and #18-Competitiveness Factors and Industry Outlook. Information from items #8 and #11 could provide insight as to whether foreign sources have better technologies, quality, or prices. Item #18 provides additional insights into the industry's ability to compete in foreign markets, such as barriers to entry.

Analysis.

This analysis of the BIS data identifies trends and correlations related to the key themes of innovation and export controls. It also provides an opportunity to consider any alternate explanations, such as political, economic, or environmental events, which may have affected innovation in the space industry. Much of the data provided by BIS included text comments requiring coding to group them into categories using the same method as in Part I. The large sample size used in the BIS survey proved beneficial as a few significant themes surfaced through the analysis despite some variation in the responses.

Part III: Comparison Analysis

The purpose of the final part of this research was to compare the perceptions gathered from Part I with the quantitative data gathered from the analyzed data of Part II. The survey data present a numbers-based picture of the state of innovation in the space industry. The perceptions from government and industry space leaders are based on personal experiences and instincts they have developed through years of participation in the space enterprise. The dynamic nature of space technology development and innovation in the last forty years provides a rich background on which many space leaders can base their perceptions. Part III of this analysis examines whether the perceptions agree with the survey data and explore possible trends that the U.S. industry, as well as U.S. policy makers, should consider regarding current export control policies.

Summary

The methodology for this research uses a three-part approach. It includes a qualitative analysis of data collected from interviews of industry experts to determine existing perceptions, a secondary analysis of data collected from a recent survey to quantify the state of space innovation, and a comparison of the perceptions with the survey data to explore the relationship between ITAR and innovation in the U.S. space industry.

IV. Results and Analysis

This chapter presents the results and analysis of the research according to the framework of the research methodology established in Chapter III. The first section provides a comprehensive qualitative evaluation of the interview data collected to establish the prevailing perceptions from the Space Enterprise. The second section provides an analysis of the 2006 survey data obtained from the Department of Commerce's Bureau of Industry and Security. Finally, the interview and survey data are combined in a comparison analysis to provide conclusions about the relationship between ITAR and innovation in the space industry.

Perceptions from the Space Enterprise

The interview data was coded using content analysis, as described in Chapter III, to organize the raw responses into dominant themes with supporting concepts. Because of the open-ended nature of the interviews, responses are not categorized by each specific question asked. However, the responses fit into four themes that structure this analysis. The themes are "Effects of ITAR on Innovation in the Space Industry," "Evolution of the Space Industry with Current Export Control System," "Recommendations to Improve Innovation in the Space Industry," and "Additional Insights for Innovation in the Space Industry." Though the sample size is small, the data collected is an appropriate representation of perspectives from the space community based on information gathered in the literature review.

Effects of ITAR on Innovation in the Space Industry.

The primary goal of this research is to explore the effects of ITAR on innovation in the space industry. Respondents were directly asked to provide their perceptions of this topic. The following paragraphs explain the most common responses in addition to a few of the unique responses. In general, respondents said that ITAR makes U.S. companies less competitive in the global space market. It inhibits our competitive stance throughout the world by restricting the sale of components or technologies that are readily available from other sources. The effects mentioned may pertain to innovation, changes to business approaches, or unintended consequences. Table 3 summarizes the specific groupings of responses discussed in this section.

Table 3: Effects of ITAR on Innovation in the Space Industry

Concept	# of Responses	% of Respondents
Increases costs - High cost for compliance	9	52.94
Timelines too long	8	47.06
Difficult to understand the rules	7	41.18
Hassle - too hard to work with the process	7	41.18
Little/No effect on innovation	7	41.18
Encourage foreign competition	6	35.29
Unable to market/sell to foreign	5	29.41
Stalls communication/sharing knowledge	5	29.41
Withdraw from space industry	4	23.53
Weak business case	2	11.76
Avoid risk	1	5.88

*Percentages reflect the frequency of responses in the interviews; respondents cited multiple answers

The most commonly mentioned (52% of respondents) effect of ITAR is that it increases costs for space products and services. Working in a restricted market drives costs up. The primary cause for this is the high cost of compliance. Companies end up

paying lawyers to figure out how to comply with ITAR. They must also pay fees to the government for compliance. Registration alone is difficult for small businesses. A company must invest significant effort and funds to maintain a compliance program. Due to the uniqueness of space missions, companies are not able to benefit from an economy of scale. These factors add cost and overhead to any contract, making it difficult to meet an international price point.

Approximately half of the total responses to this question refer to longer timelines resulting from ITAR requirements. The export licensing process takes too long. Many acknowledge that the U.S. has superior technology, but customers may not be willing to go through the involved process of licensing and subsequently choose to avoid the substantial waiting period. Congress must also process the licensing request if the sale is above a certain dollar threshold, which most space programs typically exceed. Congress's process can average approximately three months in addition to the standard licensing process. Furthermore, ITAR reduced the ability to make quick deals. It is difficult for U.S. companies to accommodate the quicker timelines that foreign customers desire.

Over 40% of the respondents commented that ITAR has little or no effect on innovation. The impact of ITAR is not necessarily in the area of innovation. They explain that there is much innovation in the industry; however, ITAR complaints emerge when trying to market outside of the U.S. or when looking for a launch provider. Some companies do not consider ITAR until after something is invented. ITAR's effect on marketing is a concept that was mentioned by 29% of respondents. The market is more restricted for lower-tier businesses. For example, a Tier 3 company can sell to Tier 1 and

2 businesses, but it is harder for them to sell to foreign customers. There are many innovative companies in the U.S., but a restricted market drives costs up and pushes the improvement cycle out. ITAR may cause the innovation process to take a little longer while trying to stay within the rules for communication. This is related to the concern of 29% of respondents that ITAR affects communication and knowledge sharing. ITAR hinders free technical exchange between a company and foreign engineers because a license is required before the communication can happen. When marketing to overseas customers, a company is able to share only a very limited amount of information, which makes their marketing efforts ineffective. Innovation can also occur when knowledge from others is shared or imported. ITAR prevents the sharing of knowledge, which means the U.S. is not always able to know about others' technologies. The U.S. is unable to benefit from this input to innovation.

Respondents also expressed great frustration with the hassles of the ITAR process. ITAR has reduced the ability to make quick deals because of the timeliness of the licensing process and requirements such as requiring a purchase order in order to get a license. A license may have many restrictions making it difficult to conduct productive anomaly resolution, the process of analyzing the cause of, and recovering from, hazards to a space mission. ITAR hassles also turn away potential foreign customers. Europe and others are moving away from ITAR components because of the hassle of third-party transfers. They also choose not to buy from the U.S. because of the possibility of DoS disallowing the transaction because of U.S. priorities.

Much of the frustration experienced by the space industry is due to a lack of understanding of the rules. This is one of the biggest hurdles for small businesses. One

respondent referred to a paranoia that causes companies to protect their technology needlessly under ITAR. They need to be educated on the licensing process to overcome the fear or ignorance of the unknown. Some of the confusion happens because it is difficult to determine when space technology is munitions. One respondent stated that industry must be cognizant of consequences and risks of illicit trade and nefarious end-use. Another respondent commented that the best you can do is to be diligent and sincere in trying to comply.

According to 35% of respondents, an unintended effect of ITAR is that it encourages foreign competition. Since the U.S. cannot export many space technologies, foreign governments are investing in their own R&D. On the same note, ITAR caused some companies to move offshore to work around the rules thus driving research outside the U.S. As a result, there are many products and high-tech resources competing with U.S. technologies. One respondent mentioned that India thanked the U.S. for ITAR because it enabled development of their indigenous space capability.

As a secondary effect, companies may modify their business approach. Three of the concepts mentioned by respondents indicate this behavior. Because companies are limited to the domestic market, they are more likely to avoid risk in developing new technologies in order to provide mission assurance. When considering opportunities beyond the domestic market, companies must balance the cost of complying with ITAR with the expected return. Companies may question the worth of staying in the space industry. This leads to companies choosing to withdraw either from individual projects or from the industry altogether. The punitive threat of violating ITAR is so great that some companies are unwilling to risk questioning if ITAR applies. They usually assume

that ITAR does apply and walk away from the business opportunity. In some cases, companies choose to abandon the space industry and transition their technologies to a different industry. In addition, many times larger companies that do not necessarily have a focus on innovation acquire small companies.

Evolution of the Space Industry with Current Export Control System.

Looking to the future, respondents considered how the space industry would evolve if there was no change to the U.S.'s approach toward export controls. The dominant concept, mentioned by almost half of all respondents, was that of a continued drawdown of U.S. suppliers (see Table 4). Considering the number of U.S. suppliers in the industry has decreased since 1999, there is a threat that suppliers will not survive because manufacturers choose to rely on imported goods. Companies consider leaving the space industry if there is a lack of market base and look towards shifting their business lines from space to other industries, such as medical or energy. This can lead to a death spiral for critical technologies in the U.S. where there may no longer be as many satellites built domestically. As a result, there is a potential secondary effect on the domestic launch capability – if there are fewer satellites built in the U.S. there is less need for U.S. launches, and U.S. space launch may slowly disappear, or in a best case, may provide a diminished capability.

Table 4: Evolution of the Space Industry with Current Export Control System

Concept	# of Responses	% of Respondents
Continued drawdown of U.S. suppliers	8	47.06
Dependence on defense/government support	3	17.65
Continued increase in costs	3	17.65
Hassle - too hard to work with the process	2	11.76
Longer timelines	2	11.76
Lost business opportunities	1	5.88
More foreign competition	1	5.88
Push reform of export controls	1	5.88

*Percentages reflect the frequency of responses in the interviews; respondents cited multiple answers

Related to supplier drawdown, 17% of respondents commented on the industry's high dependence on government support. Some may argue that the U.S. space industry is only lingering because of defense and government support. Since the DoD and other government agencies are the principal customers of the space industry, ITAR comes into play for many business opportunities outside the U.S., resulting in less export opportunities. With a limited domestic commercial market base and limited opportunities to export, the U.S. government will have to fund and manage the U.S. space industrial base to keep it alive.

Respondents expect that under current export controls, costs will continue to increase. Companies pass the high cost of ITAR compliance to customers through higher cost of products and additional overhead costs on contracts. Respondents (11.76%) also expect that innovation will continue, but will require more planning and coordination due to the hassle of dealing with ITAR and long timelines required in the licensing process.

There were several other expectations mentioned by respondents. More foreign competition is likely because other countries will continue their technology development

to meet their own needs. U.S. companies will likely have many lost business opportunities due to ITAR restrictions or choosing to walk away from potential sales to avoid ITAR hassles. Finally, the evolving global economy along with ITAR frustrations will increase momentum for reform of export controls.

Recommendations to Improve Innovation in the Space Industry.

The majority of recommendations provided by respondents to improve innovation in the space industry related to ITAR. This most likely occurred because respondents recognized the overall context of this research focuses on ITAR. In any case, 23 of the 28 recommendations (82%) suggested changes to various aspects of ITAR (see Table 5). The most popular recommendation (41%) was to review and revise the USML. Despite the frustration caused by ITAR, respondents unanimously agree that ITAR is necessary for national security. However, the majority of them also suggest there needs to be a review of ITAR and the USML with a focus on determining what really requires protection. This should be done by convening an industry-government consortium consisting of technically astute developers to identify the important technologies or items to be protected. There is support for removing satellite components from the USML with some exceptions. One respondent suggests creating three categories of technologies: (1) "in the world" – no protection is needed for these technologies; (2) "just beyond the state of the world" – not militarily critical technology; and (3) "critical military or intelligence technology" – by capability, not parts. Further, the government must develop a process to periodically review and update the list every year to 18 months. The recommendation (17%) to transfer items between the USML and the CCL closely relates to revising the USML. When reviewing the USML for updates, it may be determined that some

technologies still need protection, though not under ITAR. Depending on the situation, these technologies can be transferred to the CCL to be protected under the jurisdiction of the Department of Commerce.

Table 5: Recommendations to Improve Innovation in the Space Industry

Concept	# of Responses	% of Respondents
ITAR: Review/revise USML	7	41.18
ITAR: Update/re-focus export controls	6	35.29
ITAR: Clarify/simplify ITAR language	4	23.53
ITAR: Transfer between USML & CCL	3	17.65
ITAR: Streamline/shorten licensing process	3	17.65
Encourage communication	3	17.65
Provide more government funding	2	11.76
Total	28	

*Percentages reflect the frequency of responses in the interviews; respondents cited multiple answers

Next, there is a need to update and re-focus export controls (35%). The government has some responsibility through policy regulation to mitigate risks to security and manage commerce in a way that preserves the viability of the industrial base. The main concern should be to keep the technological lead rather than protecting specific parts. ITAR should not restrict scientists and engineers from participating in anomaly resolution when it is in the U.S.'s best interest. Updates should include applying conditions that are more creative than just saying "no."

Respondents (23%) also suggest that the ITAR language requires clarification or simplification so that companies can have a better understanding of the rules. Currently, interpretation of the law seems to be a matter of opinion; a rational interpretation is necessary to aid in clarifying the rules for export controls. One respondent suggests putting definitions into ITAR that would clarify what the Department of Commerce

controls and what the State Department controls. Another suggestion is to include a list of specific exclusions so that companies do not need to submit a license request for all export items. One respondent commented, "While simplicity of language is an extremely important aspect of communication, there is no substitution for training and education to translate national policy into reality."

Another recommendation is to streamline or shorten the licensing process. A common complaint has been the time it takes to get an export license. As stated earlier, it is neither a predictable nor a timely process, making it difficult for companies to compete in the global market. One respondent suggests improving the Technical Assistance Agreement (TAA) process by granting a general license rather than requiring the submission of specific questions.

Additionally, there are two recommendations to improve innovation in the space industry that do not necessarily relate to ITAR. The first recommendation is to encourage more communication. In the context of this research, this includes collaboration with foreign governments, companies, or individuals. Collaboration enables innovation by learning more through interaction with others. One respondent suggests innovation is more likely to occur by having a large number of small groups looking at a similar problem. This may indicate support for having more lower-tier and small businesses in the space industrial base. It also considers the inclusion of foreign groups in innovative problem-solving. In any case, more freedom of communication is necessary as it encourages innovation.

The other non-ITAR recommendation is to provide more government funding. Programs to support Science, Technology, Engineering, and Mathematics (STEM) could

encourage a more innovative culture. Government investments in development could support the U.S. industrial base and enable competition with foreign suppliers.

Additional Insights for Innovation in the Space Industry.

In addition to the perceptions and recommendations provided, respondents provided some additional insights to consider when analyzing innovation in the space industry. The following paragraphs discuss the concepts summarized in Table 6.

Table 6: Additional Insights for Innovation in the Space Industry

Concept	# of Responses	% of Respondents
Limited access to best talent	6	35.29
Foreign approach to export controls differs from U.S.	6	35.29
Government R&D funding to stimulate innovation	5	29.41
Understanding economics of sociopolitical environment	4	23.53
Appropriate contracting process	2	11.76
Encouraging space tourism	2	11.76
Cultural shift for youth	1	5.88

*Percentages reflect the frequency of responses in the interviews; respondents cited multiple answers

Many believe there is a limited pool of talent available for space technology-development projects that may in turn affect the innovation potential in the space industry. It appears that some of the best and brightest individuals choose to work in other industries offering higher salaries or greater prestige. Several respondents acknowledged that for some projects the best talent might be foreign nationals. In such cases, ITAR restricts their participation in the space industry. Some companies will not even consider foreign talent for space projects. In any case, many foreign students, possibly some of the hardest working, are educated in some of the best universities in the

U.S. Upon graduation, many of these students will not find employment in the U.S.; they return to their homelands and contribute to the growing competition around the globe.

The approach of foreign nations, more specifically Europe, towards space export controls differs from that of the U.S. The U.S. is the only government that controls the export of space technology unilaterally. Export controls of other nations are not as restrictive as ITAR, allowing foreign competitors to market their goods and services freely to the U.S. and other customers. Focusing on Europe's technological advancement, one respondent referred to the goal which Jean-Jacques Dordain had when he became the Director General of the European Space Agency (ESA) in 2003 – to be equal to or better than the U.S. In support of this goal, Dordain had an R&D budget dedicated to closing that gap. In addition, ESA's structure is set up as a single organization to combine and focus the efforts and resources of all its member states. This is something the U.S., just one nation with many space goals and priorities, does not seem able to accomplish.

Twenty-nine percent (29%) of respondents agree that the U.S. Government is concerned with the state of the industrial base; there are several programs already established to stimulate innovation and growth in the industrial base. These include the Small Business Innovation Research (SBIR) program, the R&D tax credit, and other funds for R&D. Some respondents questioned whether these programs are really on track to help the industry. There has been a decrease in funding for science nationally; this is not a good sign for R&D in the space industry that, as stated, depends primarily on government funds. One respondent specifically mentioned the R&D tax credit as a good incentive to stimulate R&D in U.S. companies. However, it is difficult for industry to

plan for and rely on this credit because it is a temporary measure, thus many companies do not take advantage of it. The SBIR program targets small businesses with technological potential and supports them in one or two phases of a three-phase process to commercialize their innovations. Unfortunately, some companies participating in this program struggle to make it to the third phase, which does not receive funding from the government. Many times companies become entirely dependent on government funding and never look beyond government work.

Another concept mentioned by 23% of respondents refers to global sociopolitical concerns. One respondent suggests that we have a closed market. For example, we cannot sell to Arab nations because we do business with Israel; India does not buy from other nations; space business with China is restricted. Still, global business opportunities should be encouraged because economic competition is essential for national security. Thus, ITAR licensing decisions should consider both economic competition and national security. Economic competition, as opposed to military conflict, encourages more innovation.

The way contracts are executed in the space industry may also have some effect on innovation. Because many contracts usually include cutting-edge technology development, it is common to see "cost-plus" contracts awarded to prime contractors. This option minimizes the cost risk for the contractor. However, one respondent mentioned that sometimes the prime contractors arrange "fixed-price" contracts with lower-tier companies and small businesses, which is not appropriate for development projects. These lower-tier companies and small businesses assume more cost risk and may not be willing to push their more innovative ideas. Another complaint suggests that

the government contracting process is too complex and burdensome for small businesses. One respondent asserts the DoD should put forth more of an effort to make its procurement practices friendlier to small businesses that do not have teams of attorneys to help them navigate the process. This would enable the more innovative portion of the industry to continue to provide products and services to the government.

Government requirements drive much of the space industry. However, a push for more commercial space ventures would create more innovative opportunities. Commercial space can drive innovation, particularly in space tourism, according to 11% of respondents. One respondent likens the commercial space technology movement to the early computer movement, where the government contributed the majority of investments early, which established the infrastructure. As the relevant technologies became more refined, the computer industry expanded and now individual consumers worldwide, rather than government-funded projects, drive the computer industry. Space tourism has the potential to evolve in the same way. The government has made a significant investment in space technologies. Now, savvy entrepreneurs are making innovative efforts to improve technologies for launch and human transportation in space. Perhaps a more fitting comparison may be commercial air transportation, where eventually the average person will be able to travel in and through space just as easily as traveling between continents on Earth.

One respondent mentioned a very interesting perspective on modern day innovation. He suggests we are in the midst of a “cultural shift” because of our youth’s exposure to technology at a younger level. Children learn the STEM subjects earlier; however, they also need to be taught problem solving, which does not necessarily happen

in the classroom. Adults need to encourage children to be innovative. For example, children 50 years ago found a stick, a ball, and makeshift bases to play a rough version of baseball, while today's children are provided the standard equipment, a baseball field, and coaches – there is no need to think outside the proverbial "box." Society should emphasize both STEM education and problem solving skills to encourage innovative thinking.

Space Innovation Survey Analysis

The Commerce Department's survey data used for this research is grouped in two categories, context and innovation indicators. The analysis of the context sets the background for the relationship to export controls such as ITAR. Then a discussion of the indicators of innovation follows to understand the state of innovation in the space industry.

Context for foreign competition and export controls.

Survey item #8 asked respondents to identify all the reasons for procuring products or services from foreign vendors. Response options were as follows: Better quality, Not made in the U.S., Less expensive, Better technology, Business relationship, Trade offset, Service after sale, Foreign subsidies, Customer preference, and Other. The responses selected most frequently were: Not made in the U.S. (19.18%), Less expensive (17.89%), Better technology (15.52%), Business relationship (14.66%), and Other (12.93%). Table 7 presents this information – each column of data reflects the frequency of the reason in each Tier group. For example, 17 Tier 1 companies, 39 Tier 2

companies, and 33 Tier 3 companies listed 'Not made in the U.S.' as a reason for foreign sourcing. These numbers, when combined, represent 19.18% of all responses in all tiers.

Table 7: Reasons for Foreign Sourcing

Reason	# Responses	% Responses	# Responses by Tier		
			Tier 1	Tier 2	Tier 3
Not made in the US	89	19.18%	17	39	33
Less expensive	83	17.89%	19	41	23
Better technology	72	15.52%	10	25	37
Business relationship	68	14.66%	10	35	23
Other	60	12.93%	5	30	25
Customer Preference	39	8.41%	5	14	20
Better Quality	34	7.33%	2	17	15
Service After Sale	17	3.66%	0	5	12
Trade Offset	1	0.22%	0	0	1
Foreign Subsidies	1	0.22%	0	0	1
Total	**464**	100%			

*Percentages reflect the frequency of responses; respondents cited multiple answers. Total # of respondents in Tiers: Tier 1 = 40, Tier 2 = 82, Tier 3 = 80

Approximately half of "Other" responses mention that there is no known domestic source available. This adds more weight to the top response – Not made in the U.S. This could indicate an opportunity for U.S. companies to establish a domestic source. However, the business case may not be worth the effort and resources required unless the company could compete globally.

Survey item #11 asked respondents to list the top ten directly competing foreign products or services and to specify which factors make the foreign producers competitive. The eleven listed factors are as follows: Cost, Product performance, Product quality, Access to raw materials, Bonus features/services, Delivery time/scheduling, Foreign exchange, Export licensing requirements, Trade/offset arrangements/subsidies, Ability to

pay bribes/kickbacks, and Other. Each respondent listed ten items resulting in 2022 items with competitiveness factors. The Top 5 factors making foreign producers' products competitive (see Table 8) are Export licensing requirements (listed 256 times), Cost (154), Trade/offset arrangements/subsidies (87), Product performance (84), and Other (76). The most common reason listed under "Other" was a Preference for indigenous/domestic sources or capabilities (listed 32 times for Tiers 2 & 3).

Table 8: Top Five Factors for Competitive Foreign Products

Factor	# of occurrences	% of total responses
Export licensing requirements	256	12.66
Cost	154	7.62
Trade/offset arrangements/subsidies	87	4.30
Product performance	84	4.15
Other	76	3.76

*Percentages reflect the frequency of responses; respondents cited multiple answers

Survey item #18 contained five sub-questions and considered competitiveness factors in the space industry. Specifically, the survey item looked at companies' past and planned actions to improve their competitiveness, possible U.S. Government actions to improve their competitiveness, effects of government expenditures, and barriers to entry in foreign countries. The question regarding government expenditures did not provide relevant inputs for this research and therefore is not discussed. There were 183 responses to survey item #18; some responses included multiple actions. Respondents were asked for actions taken in the last five years as well as actions they plan to take in the next five years to improve competitiveness. For both periods, the top three actions are (see Tables

9 and 10): technology and product development, process improvements, and managing costs. Some ITAR-related actions appeared for the previous five-year period and focused mainly on hiring or training ITAR expertise. However, plans for the next five years included more attention towards improving competitiveness by overcoming or "working around" ITAR restrictions. Some examples of actions planned to take include repackaging product lines to remove ITAR restrictions, lobbying to revise ITAR, acquiring or merging with foreign companies to establish a foreign affiliate not subject to ITAR restrictions, and at the extreme, withdrawing from or avoiding space-related business.

Table 9: Past Actions (Last Five Years) to Improve Competitiveness

Action	# of occurrences	% of total responses
Technology and product development	32	17.49
Process improvements	27	14.75
Manage costs	27	14.75
Train/hire ITAR expertise	2	1.09

*Percentages reflect the frequency of responses; respondents cited multiple answers

Table 10: Future Plans (Next Five Years) to Improve Competitiveness

Action	# of occurrences	% of total responses
Technology and product development	39	21.31
Process improvements	29	15.85
Manage costs	18	9.84
ITAR-related actions	8	4.37

*Percentages reflect the frequency of responses; respondents cited multiple answers

With regard to government actions, respondents provided suggestions for changes the Federal Government could implement to improve their competitiveness. The overwhelming majority (52%) of suggestions referred specifically to ITAR or export controls (see Table 11). The most common suggestion was to review the USML and remove items from the list. One respondent commented that the "U.S. has too many restrictions for potential friendly government purchasers making it a better choice for them to select a non-U.S. supplier." The subsequent most common suggestions were to improve throughput times for TAA and export licenses and to streamline licensing procedures.

Table 11: Suggested U.S. Government Actions to Improve Competitiveness

Action	# of occurrences	% of total responses
ITAR-related responses	**95**	**51.91**
Review/remove items from USML	27	14.75
Improve throughput time for licenses	19	10.38
Streamline licensing procedures	14	7.65

*Percentages reflect the frequency of responses; respondents cited multiple answers

The most insightful part of this survey item was the request for the five most significant barriers companies face when attempting to market products in foreign countries. The most common barrier listed is ITAR and export controls, cited in 162 responses (see Table 12). ITAR was as a barrier for 23 of the 30 countries mentioned in the numerous responses. Another common barrier is a foreign country's bias toward its own domestic suppliers.

Table 12: Barriers to Entry in Foreign Countries

Action	# of occurrences	% of total responses
ITAR-related responses	162	88.52
Bias toward domestic suppliers	36	19.67
EU limitations on foreign content	5	2.73

*Percentages reflect the frequency of responses; respondents cited multiple answers

Indicators of innovation.

Survey item # 20 (line a) allowed respondents to place a monetary value on patents and trademarks. The assessment used both business unit and corporate figures. At least 70 (or 35%) of the 202 respondents recorded "Intangibles" in each financial reporting year. In any given year, the average value of "Intangibles" was two to three times the "Property, Plant, and Equipment (PP&E)" line item. This shows that companies that provided a response for this line considered “Intangibles,” which includes intellectual property such as patents and trademarks, to be very valuable. However, the larger percentage of respondents did not provide data for this line, which could indicate “Intangibles” are a low priority for many companies. It is also possible that companies did not provide this information because it may be proprietary. Within this reported figure, there was no further breakout of values for patents or trademarks. Also, tier breakouts were not provided for this survey item.

In survey item #5, respondents provided information on their domestic and foreign sales in the space business from 2003 to 2007. Across all three tiers and spanning the five year period, foreign sales accounted for a very small percentage of total sales. Tier 1 foreign sales averaged 8.85% of total sales, Tier 2 averaged 7.10%, and Tier 3 averaged 5.67% (See Table 13). This indicates that U.S. companies have limited

participation in the global market. It is interesting to note that there was an approximately 3% drop in foreign sales for Tier 1 companies from 2003 to 2004 and a second approximately 3% drop from 2004 to 2005. Tier 2 companies also showed a slight decrease in foreign sales while Tier 3 foreign sales remained consistent. From 2005 to 2007, all Tiers showed an increase in foreign sales. The reason for the decrease in percentage of foreign sales was not directly part of the scope of this research; however, a possible explanation is that an increase in foreign innovation has created more competition for U.S. products and services, offering other options from which foreign customers can choose.

Table 13: Space Related Foreign and Domestic Sales

	All Tiers					Tier 1					Tier 2					Tier 3				
	2003	**2004**	**2005**	**2006**	**2007**	**2003**	**2004**	**2005**	**2006**	**2007**	**2003**	**2004**	**2005**	**2006**	**2007**	**2003**	**2004**	**2005**	**2006**	**2007**
Foreign Sales ($M)	3744	3176	2691	3942	3392	3159	2573	1994	2825	2363	511	520	600	995	894	75	83	97	122	134
Domestic Sales ($M)	31948	36966	43545	47346	32375	23400	27234	32169	35506	20108	7133	8175	9646	10066	10335	1414	1557	1729	1774	1933
Total Sales ($M)	35692	40142	46236	51288	35767	26559	29807	34163	38331	22471	7644	8695	10246	11061	11229	1489	1640	1826	1896	2067
Foreign % of Total	10.49	7.91	5.82	7.69	9.48	11.89	8.63	5.84	7.37	10.52	6.68	5.98	5.86	9.00	7.96	5.04	5.06	5.31	6.43	6.48
Average Foreign %	8.28					8.85					7.10					5.67				

*2007 data are estimates

Survey item #22 solicited R&D expenditures supporting space-related activities. Respondents reported these values in four categories: Basic Research, Applied Research, Product Development, and Process Development. R&D expenditures are primarily targeted towards Basic Research (42.1%) and Product Development (34.3%), followed by Applied Research (21.5%) and only minimal investment in Process Development (2.1%) (see Table 14). Of note, survey data shows that R&D expenditures increased an average of 8% per year from 2003 to 2006.

Table 14: Space R&D Expenditures by Year

	2003 ($M)	2004 ($M)	2005 ($M)	2006 ($M)	Total ($M)	% of Total R&D
Basic Research	713	788	963	991	3455	**42.1%**
Applied Research	354	477	474	460	1765	**21.5%**
Product Development	721	646	672	775	2814	**34.3%**
Process Development	50	48	34	43	175	**2.1%**
Total	1838	1959	2143	2269	8209	**100%**

Table 15 shows Space R&D expenditures by Tier. Tier 2 expenditures account for almost half (47.6%) of total R&D expenditures. Tier 1 was responsible for 24.8% of the total while Tier 3 conducted slightly more R&D expenditures at 27.5%. This evidence supports the idea discussed in Chapter II that the lower tiers (specifically Tier 2) are a significant source of innovation.

Table 15: Space R&D Expenditures by Tier

	Tier 1 ($M)	Tier 2 ($M)	Tier 3 ($M)	Total ($M)
Basic Research	789	1627	1040	3456
Applied Research	750	808	207	1765
Product Development	456	1396	961	2813
Process Development	44	79	54	177
Total	2039	3910	2262	8211
% of Total R&D	**24.8%**	**47.6%**	**27.5%**	**100%**

Respondents also provided figures for funding received from the following identified sources: Parent Company (Internal), Federal Government, State and Local Government, U.S. Private Entity, Foreign Investors, and Other. The two primary sources are Internal and the Federal Government, each providing approximately 50% of the total R&D funding (see Table 16). The remaining sources combined provided only approximately 1% of the total. The substantial percentage of investment for R&D from internal sources combined with government sources may be considered a strong indicator of innovation.

Table 16: Funding Sources

	2003		2004		2005		2006		Cumulative	
Funding Source	**Actual**	**% of Annual Total**	**Actual**	**% of Annual Total**	**Actual**	**% of Annual Total**	**Actual**	**% of Annual Total**	**Total**	**% of Total**
Parent/Internal/ IRAD	$ 965	50.42%	$1,005	48.06%	$ 1,218	53.75%	$ 1,271	52.18%	$ 4,459	51%
Federal Government	$ 927	48.43%	$1,061	50.74%	$ 1,015	44.79%	$ 1,130	46.39%	$ 4,133	47%
Other	$ 22	1.15%	$ 25	1.20%	$ 33	1.46%	$ 35	1.44%	$ 115	1%

As mentioned in Chapter II, the most frequently used proxy for measuring innovation is R&D expenditures, and is typically expressed as a proportion of sales. Combining the data for survey items #22 and #5 provides the ratio of R&D expenditures as a percentage of total space sales (see Table 17).

Table 17: R&D Expenditures as % of Total Space Sales

	2003 (%)	2004 (%)	2005 (%)	2006 (%)	Average (%)	Tier Average (%)
Tier 1 (IRAD)	0.43	0.47	0.44	0.42	**0.44**	**1.59**
Tier 1 (Gov't)	1.03	1.43	1.11	1.01	1.15	
Tier 2 (IRAD)	6.53	5.88	6.78	6.75	**6.49**	**11.34**
Tier 2 (Gov't)	5.86	4.75	4.14	4.68	4.86	
Tier 3 (IRAD)	24	22	20	19	**21.25**	**34.00**
Tier 3 (Gov't)	14	13	12	12	12.75	

The average values from 2003 to 2006 are: Tier 1 = 1.59%, Tier 2 = 11.34%, Tier 3 = 34%. The ratio of internal Independent Research and Development (IRAD) as a percentage of total space sales averaged as follows: Tier 1 = 0.44%, Tier 2 = 6.49%, Tier 3 = 21.25%. These percentages indicate a greater potential for innovation to occur in Tier 2 and Tier 3 firms. The data also show the Tier 3 percentages decreasing over the recorded period; this could be an indication of decreasing innovation.

Comparison Analysis

This section pulls together the perceptions from the interviews and the quantitative analysis gathered from the survey data. There are several key concepts that

correlate between the two data sources. There are no apparent disagreements between the data sources – the survey data supports the majority of interview respondents' comments. The following paragraphs summarize the key concepts.

The most obvious relationship between the interview data and the survey data is the agreement on recommendations to improve ITAR. The fact that ITAR-related responses emerged more frequently in both contexts signifies that ITAR appears to have an influence on competitiveness and innovation. The top recommendations reported in both Tables 5 and 11 are to revise the USML and to streamline the licensing process. Though these recommendations may not have a direct impact on innovation, they may improve the competitive environment to stimulate more innovation.

There is also agreement between both data sources on the need to stimulate more innovation with government funding. As shown in Table 15, Tier 2 companies are responsible for almost half of the total R&D expenditures for space. In Table 17, data shows that Tier 2 and Tier 3 companies use more IRAD funding than government funding. Both of these tables demonstrate the high expectation for innovation to occur at these tiers. Therefore, if Tier 2 and Tier 3 companies received more government funding, they would have more resources available with which to be more innovative. The recommendation to provide more government funding in Table 5 stems from a general concern that science and technology is a low priority for the federal government. This is echoed by the additional insight provided by respondents (see Table 6) to consider the effectiveness of government programs already in place to support R&D.

Another common concern in both data sources is the apparent unintended consequence of ITAR restrictions – increased foreign competition. The combined effects

of ITAR, as outlined in Table 3, serve to encourage foreign competition. Foreign products have become more desirable because ITAR has caused increased costs, longer timelines, and complicated licensing requirements for U.S. products. These factors are pushing innovation overseas; foreign customers do not want to deal with these restrictions. Therefore, they develop their own technologies to provide the same capabilities. Currently, the high cost for compliance (Table 3) is absorbed into the cost for space products and services. Foreign sources are able to offer less expensive options (Table 7) which is one of the top factors (Table 8) making foreign products more competitive. Interview respondents expect that costs will continue to increase under the current export control system. However, the greatest deterrent for purchasing U.S. products is the hassle of dealing with export licensing requirements (Table 8). Unfortunately, this is not likely to change under the current system of rules (Table 4). With increased foreign competition and the hassles of the licensing process, ITAR is a major contributing factor in lower-tier U.S. companies' decision to withdraw from the space industry. Subsequently, this diminishes the available resources for innovation in the space industry.

Summary

The interview data revealed some key themes in the perceptions of participants in the space industry. These themes were effects of ITAR on innovation in the space industry, how the space industry will evolve with the current export control system, recommendations to improve innovation in the space industry, and some additional insights for innovation in the space industry. The analysis compared concepts within

these themes with quantitative data gathered from BIS's 2006 survey. This analysis presented several key concepts common to both data sources that include recommendations to improve ITAR, more government funding to stimulate innovation, and increased foreign competition as an unintended consequence of ITAR.

V. Conclusions and Recommendations

The purpose of this research was to explore the connection between ITAR and its effects on space innovation. This chapter outlines the concluding concepts resulting from this research. The first section provides the research conclusions as answers to the research questions. The next section outlines recommendations to consider for potential government policy revisions. The subsequent section summarizes the limitations of this study. Finally, the last section proposes future research areas to expand on the current topic.

Research Conclusions

Based on the comprehensive literature review and the analysis of data from interviews and the BIS 2006 survey, research conclusions provide are offered as answers to the investigative questions outlined in Chapter I along with a summary of the innovation measures outlined in Chapter II.

Research Questions.

1.   What are the effects of ITAR restrictions on innovation in the U.S. SIB?

This research did not reveal significant evidence that ITAR has a direct effect on innovation. The space industry has experienced some negative effects as a result of ITAR restrictions, such as increased costs due to compliance requirements and increased timelines due to the lengthy licensing process. These negative effects hinder the ability to compete in the global market, thus making growth for lower-tier companies difficult to

achieve. The industry may expect some secondary negative effects on innovation due to lower-tier companies abandoning the space industry, leaving a void in its primary source of innovation. This is already a risk for key technology areas where there are only one or two domestic suppliers, such as radiation hardened electronics and solar arrays. Companies specializing in these technology areas may not be able to compete in the global market due to ITAR restrictions; however, foreign companies are allowed to compete with them in the US market, making their survival challenging. If a company remains in the space industry, funds for ITAR compliance activities may be diverted from funds for internal R&D investments, thus reducing the potential for innovation.

2. *Are there any indications that innovation in the SIB is declining since stricter ITAR restrictions were imposed in 1999? If so, what are they?*

The most useful indicators of innovation in the space industry are R&D expenditures as a percentage of total space sales and U.S. market share data over a ten-year period. The R&D expenditures data revealed a greater potential for innovation to occur in Tier 2 and Tier 3 companies because of a greater percentage of investment in R&D. There was a decrease in Tier 3 percentages from 2003 to 2006, which may indicate a decline in innovation, but a causal relationship cannot be inferred with certainty.

The market share data reveals a decrease in the U.S. share of global satellite manufacturing, indicating a potential decline in space innovation. The DoD attributes the decrease in market share to U.S. export controls and foreign policies to increase indigenous capabilities (Taylor 2007). Within this context, it is possible to assume that

U.S. innovation has not changed, but an increase in foreign innovation has caused the U.S.'s decreased market share of the space industry.

3. *What is the perception of the health of innovation in the SIB from space leaders in government and industry?*

The general perception is that innovation in the space industrial base is healthy. U.S. companies are able to develop products and services to meet the unique needs of their customers. Interview respondents feel confident in the U.S.'s ability to innovate and lead the space industry with superior technologies. However, U.S. export control policies threaten this ability because they limit participation in the global space market. Respondents expressed concern that innovation in the space industry will suffer if there are no changes to the current export control system.

Strength of Innovation Measures.

Chapter II outlined six innovation measures to consider in this research. These are R&D expenditures, Intellectual property, Number of new products introduced, Percent of sales or profits from new products, U.S. market share of the space industry, and Global market-share data over several years. Of the six, this research is able to address four measures. Data collection efforts were unsuccessful in obtaining enough information to make any judgment regarding the Number of new products introduced and the Percent of sales or profits from new products.

The survey data and the interview data provided very little insight into the role of intellectual property in the space industry. For 35% of survey respondents, intellectual

property is valued highly. Only 23% of interview respondents provided information on intellectual property. This information did not reveal any dominant opinion towards the value of intellectual property. Some companies seek to publish technical papers and apply for multiple patents while others place little to no value on these documented forms of intellectual property. Other possible explanations are that companies do not want to share this information, or the respondents did not know the information at the time.

As discussed earlier, Space R&D expenditures from the survey data show that Tier 2 and Tier 3 companies spend a greater amount as a percentage of total space sales than Tier 1 companies do. This leads us to assume that lower-tier companies place greater importance on the ability to innovate. Interview data did not provide any additional insights into actual expenditures. However, some interview respondents reiterated the concept that lower-tier companies are a primary source of innovation. Therefore, protecting this innovation capability should be a high priority for U.S. policymakers.

The current research did not collect data to discuss U.S. market share of the space industry and Global market share data over several years. However, the DoD's defense industrial base assessment of the U.S. space industry (Taylor 2007) includes some relevant market share data which was collected by the Satellite Industry Association (SIA). Based on SIA's 2004 and 2006 reports, the U.S. share of global satellite manufacturing has decreased over a ten-year period. U.S. market share was 63% in 1996-1998 and dropped to 52% in 1991-2001 and to 42% in 2002-2006. The DoD's report attributes this decrease in market share in part to U.S. export controls as well as foreign policies to increase indigenous capabilities. Without this context, it is possible to

assume that the U.S. space industry is becoming less innovative. The more likely explanation is that U.S. innovation has not changed, but foreign innovation has increased, resulting in the U.S.'s decreased market share of the space industry. Other explanations could be that the rate of U.S. space innovation has decreased or that innovation is a lagging indicator. There was insufficient long-term data available to draw specific conclusions on the cause of the decreased market share.

Recommendations

The policy implications of this research are not solely for ITAR. A multi-faceted policy approach could foster more innovation in the U.S. space industry. This research led to the following recommendations for U.S. policymakers.

The current administration already has efforts underway to investigate potential reforms for U.S. export policies. Policymakers must tread carefully in these efforts because changes to export policies can have major effects on national security as well as U.S. economic growth. The top priority is to determine *what* to protect and at *what level* to protect to ensure U.S. national security. The USML requires review and updates to account for the current state of space technologies around the world. If an item or a technology can be removed from the USML, consideration should be given to other export protection options such as the CCL. Policymakers must also consider how to implement and enforce protections to avoid causing unnecessary barriers to industry growth and U.S. economic growth. As stated, this is the primary source of frustration for space businesses. The Department of State has made efforts to streamline the current

licensing and TAA processes, but perhaps they should consider replacing the current process with a new and better process.

In addition to export policy reform, the administration should review government programs to encourage science and technology in the industrial base. The intent of this recommendation is not to suggest the government should pay for more innovation. Rather, the government should structure policies and regulations to minimize obstacles for small businesses while protecting the rights of U.S. citizens. For example, a permanent extension of the R&D tax credit would encourage U.S. companies to plan and invest in long-term research projects. In addition, the government could bolster programs such as SBIR to target lower-tier businesses and encourage more innovation. However, it is not enough just to develop a great technology. The true benefit of innovation is in the implementation of new technologies – this may be where small businesses need more help.

Limitations of the research

The literature review presented several options for measuring innovation along with criticisms of some of these options. Though justification was provided for the measures used in this research, the reader must consider that there are weaknesses associated with all the measures. They are good indicators of the potential for innovation to occur, but insufficient to determine the cause of innovation. Therefore, it is difficult to determine if the transition of jurisdiction for all satellites and satellite technologies to ITAR (referenced in Chapter I) was the cause for any observed effects on innovation as

measured in this research. Furthermore, other considerations for a causal analysis could include:

- The terrorist attacks of September 11, 2001
- The economic outlook for the space industry as well as for the nation
- A minimal need to replace existing capabilities – perhaps the demand for space technology has not increased because innovation has been so good and has provided technologies that do more for longer
- The possibility that negative effects due to ITAR changes have been underreported

Another limitation is the use of derivative data. This may be a concern because of the danger of incorrectly interpreting the information originally collected for a different purpose.

Future Research

This thesis reveals a need to examine other second or third order effects of ITAR. It is worth looking into disciplines other than space technology to investigate the effects of ITAR in economic, social, and political environments. Such studies could advise the government's current efforts to reform ITAR. The following paragraphs offer four suggestions to fill gaps not addressed in this research and further enhance the knowledge base encompassing the current research.

The current research did not collect data on the number of new products introduced and the percentage of sales or profits from new products. A follow-on study

could focus on these measures to gain better insight as to the state of innovation in the U.S. space industry.

Since this research was unable to clearly identify a direct causal relationship between ITAR and any significant change in space innovation, subsequent research could investigate contributing factors to the decrease in U.S. market share of the global space industry and to what degree these factors contributed.

Further study is necessary to establish concrete measures of innovation. If measures cannot be generalized to all situations, perhaps a study to present conditions for determining which measures can be reliably used in various situations. Current innovation measures indicate the potential for innovation to occur or whether innovation is actually occurring. However, the literature provides confusing and contradictory guidance on the validity of these measures.

The broader industry environment could benefit from an investigation of government policies, laws, and regulations that affect innovation in the U.S. industrial base. This study should explore whether current policies hinder innovation, distinguish which policies encourage innovation, and consider which policies can be helpful with some revisions.

Summary

This chapter presented the concluding thoughts resulting from this research. There is no significant evidence that ITAR has a direct effect on space innovation. However, the industry may experience some secondary negative effects on innovation. Recommendations to policymakers include reforming the overall U.S. export policy

approach and strengthening government programs that support STEM disciplines. Though some limitations of this research exist, there are several topics worthy of consideration for follow-on research efforts.

Appendix A: Interview Instrument

1. How do you or your business participate in the Space Industrial Base?

2. What are your perceptions of your business's innovation capability for space technology?

    a. Since 1999, how many patents has your business applied for? Been granted?

    b. Since 1999, how many technical papers have been published by members in your business?

    c. Since 1999, how many new ideas/products has your business introduced into the space market?

    d. Since 1999, on average, what was your percent of sales/profits from new products?

3. What are your perceptions of the effects of ITAR on your business's innovation capability for space technology?

4. What are your perceptions of the effects of ITAR on innovation in the space industry?

5. How do you expect the U.S. space industry will evolve with the current system of export control policy?

6. What other factors do you think affect innovation in the space industry?

7. If you were king/queen for a day, what would you change?

8. Do you have any additional comments regarding ITAR and the space industry?

Appendix B: Selections from BIS 2006 Survey Instrument

5. SPACE-RELATED DEFENSE & NON-DEFENSE SALES

Instructions: Please provide sales data for calendar years **2003**-**2007** for your defense and non-defense space-related products and/or services.

Note: Total **Defense** and **Non-Defense** **must** **equal** **Total** in the right column. The combination of **Domestic Sales** and **Foreign Sales** must equal **Total Sales** in the bottom row.

	2003 *(in $ thousands)*			**2004** *(in $ thousands)*			**2005** *(in $ thousands)*			**2006** *(in $ thousands)*			**2007 (estimate)** *(in $ thousands)*		
	Defense	Non-Defense	Total	Defense	Non-Defense	Total	Defense	Non-Defense	Total	Defense	Non-Defense	Total	Defense	Non-Defense	Total
Domestic Sales $															
Foreign Sales $															
Total Sales $															

8. REASONS FOR FOREIGN SOURCING

Instructions*:* For the five products and/or services cited in Question 7.b on "Foreign Procurement", please identify ALL the reasons your Company/Business Unit procured these products and/or services from Foreign vendors. If your reason is not included here, provide rationale in the space provided.

Reasons for Procuring Products and/or Services from Foreign Vendors

☑ *(Check all that apply)*

#	*Product/Service Code (from Question 3)*	*Better Quality*	*Not Made in the U.S.*	*Less Expensive*	*Better Technology*	*Business Relationship*	*Trade Offset Arrangement*	*Service after Sale*	*Foreign Subsidies*	*Customer Preference*	*Other (specify in comments below)*
1.											
2.											
3.											
4.											
5.											

Comments:

11. FOREIGN COMPETITORS – 2003-2006

Instructions: Please list the **Top Ten Foreign Products and/or Services** (by sales, largest to smallest) that **competed directly** with your Company's/Business Unit's **space-related** products and/or services from calendar year **2003-2006**. Also, specify what ***factors make foreign producers' products competitive*** relative to your Company's/Business Unit's products.

[For "Code" and "Name" Please use the Product and Service Type Listing in Question 2.]

Top Ten Foreign Products and/or Services	*Product or Service Code*	*Foreign Product Name*	*Foreign Company Name*	*Country*	☑ *(check all that apply)*										
					Cost	Product Performance	Product Quality	Access to Raw Materials	Bonus Features/ Services	Delivery Time/ Scheduling	Foreign Exchange	Export Licensing Requirements	Trade/Offset Arrangements/Subsidies	Ability to Pay Bribes/Kickbacks	*Other (specify in comments below)*
#1															
#2															
#3															
#4															
#5															
#6															
#7															
#8															
#9															
#10															

Comments:

18.	COMPETITIVENESS FACTORS AND INDUSTRY OUTLOOK
PAST ACTIONS TO IMPROVE COMPETITIVENESS	
Please describe the actions your Company/Business Unit *has taken* in the **Last Five Years** to *improve your competitiveness* in the space market?	*Comments:*
FUTURE PLANS TO IMPROVE COMPETITIVENESS	
Please describe the actions your Company/Business Unit *plans to take to improve your competitiveness* over the **Next Five Years**.	*Comments:*
U.S. GOVERNMENT ACTIONS	
Please indicate what **actions**, **policy changes** or **regulatory reforms** the Federal Government could implement to improve your Industry's and/or Company's/ Business Unit's overall competitiveness.	*Comments:*

EFFECT OF GOVERNMENT EXPENDITURES	
How have **space-related** spending and allocations by the U.S. Department of Defense, NASA, NOAA, and other agencies impacted your Company/Business Unit in the following categories?	
Products and Services	*Response →*
Personnel/Staffing	*Response →*
Operations	*Response →*
Please describe the strategies your Company/Business Unit has developed to respond to the above issues.	
Response →	

BARRIERS TO ENTRY IN FOREIGN COUNTRIES

Please provide the **five most significant** barriers to entry faced by your Company/Business Unit when attempting to market products in foreign countries. [***Note:*** List in order of relevance/impact; #1 is the most significant barrier.]

#	Country	Barrier to Entry
1.		
2.		
3.		
4.		
5.		

20.a	**FINANCIALS – BALANCE SHEET**					
Instructions: Organizations that operate as part of a larger company with non-space-related business operations should provide ***balance sheet data only*** for their **Space-Related Business**. *[Please provide estimates if actual figures are not available.]*						
Corporate Figures represented below			*← Check ☑ here*			
Business Unit Figures represented below						
My Company/Business Unit operates on a: *☑ here →*	*Fiscal Year* / *Calendar Year*		***2003***	***2004***	***2005***	***2006***	***2007 (est)***

A.	**Current Assets** *(in $ thousands)*						
1.	Cash						
2.	Marketable securities						
3.	Accounts receivable, net						
4.	Inventories						
5.	Prepaid expenses						
6.	Other current assets *(please specify)*						
7.		***Total current assets***					
B.	**Non-Current Assets** *(in $ thousands)*						
8.	Property, plant and equipment						
	*Break-out capital expenditures. **[Do not double count** PP&E in "Total Non-Current Assets."]*	**9.** *- Property*					
		10. *- Buildings*					
		11. *- Machinery & Equipment*					
12.	Investments						
13.	Intangibles (patents, trademarks, goodwill)						
14.	Less accumulated depreciation						

15.	Other assets *(please specify)*					
16.	***Total non-current assets***					
17.	***Total assets***					
C.	**Liabilities and Owners' Equity** *(in $ thousands)*					
D.	***Current Liabilities*** *(in $ thousands)*					
18.	Accounts payable					
19.	Estimated tax liability *(e.g., income taxes payable)*					
20.	Accrued expenses					
21.	Long-term debt (current portion) due in 1 year					
22.	Other current liabilities *(please specify)*					
23.	***Total current liabilities***					
E.	***Non-Current Liabilities*** *(in $ thousands)*					
25.	Long-term debt *(less current portion)*					
26.	Deferred income taxes					
27.	Other long-term liabilities *(please specify)*					
28.	***Total non-current liabilities***					
29.	***Total liabilities***					
F.	**Owners' Equity** *(in $ thousands)*					
30.	Common stock					
31.	Additional paid-in capital					
32.	***Total paid-in capital***					
33.	Retained earnings					
34.	Less treasury stock *(stock repurchase)*					
35.	***Total owners' equity***					
36.	***Total Liabilities and Owners' Equity****					

Note: Please report any significant one-time events on the next page of this survey.

22.a RESEARCH AND DEVELOPMENT

Instructions: Companies/organizations whose **sole focus** is **space-related** products should report Corporate-wide R&D **expenditures**. Those companies/organizations that are part of a larger company with other non-space-related business operations should report R&D **expenditure figures only** at the **space-related Business Unit** level. Please specify whether you are reporting Corporate R&D figures or Business Unit R&D figures with a check ☑ in the corresponding box.

SPACE-RELATED R&D – EXPENDITURES BY FUNCTION

Corporate R&D		← *check ☑ here*
Business Unit R&D		

R&D Expenditures Supporting Space-Related Activities

(in $ thousands)

CATEGORY	*2003*	*2004*	*2005*	*2006*	*2007 (est.)*
Basic Research					
Applied Research					
Product Development					
Process Development					
Total R&D					

22.b SPACE-RELATED R&D – FUNDING SEGMENT BY SOURCE

Corporate R&D		← *check ☑ here*
Business Unit R&D		

R&D Funding Sources for Space-Related Activities

(in $ thousands)

CATEGORY	*2003*	*2004*	*2005*	*2006*	*2007 (est.)*
Parent Company (internal)					
Federal Government					
State and Local Government					
U.S. Private Entity *[Includes industry, universities, and all other non-governmental organizations.]*					
Foreign Investors *[Includes private, industry, governments, and universities.]*					
Other (please specify in box below)					
Total R&D					

Other →	***Comment →***

References

Abbey, G. and N. Lane (2009). United States Policy: Challenges and Opportunities Gone Astray. Cambridge.

Adams, R., J. Bessant, R. Phelps. (2006). "Innovation management measurement: A review." International Journal of Management Reviews **8**(1): 21-47.

AFRL (2009). Air Force Annual Industrial Base Assessment, Air Force Manufacturing Technology Division.

Australia Bureau of Statistics (1996). Research and Experimental Development: Business Enterprises. Canberra.

Bessant, J. and J. Tidd (2007). Innovation and Entrepreneurship, Wiley.

Boucher, M. (2009). "ITAR Reform Legislation in the Works." Retrieved November 13, 2009, from http://nasawatch.com/archives/2009/05/itar-reform-legislation-in-the-works.html.

Business Council of Australia (1993). Managing the Innovating Enterprise. Melbourne, BCA.

"Cambridge Advanced Learner's Dictionary." (2010) Cambridge Dictionaries Online, Retrieved January 7, 2010, from http://dictionary.cambridge.org/dictionary/british/innovation.

Chesbrough, H. W. (2003). Open Innovation: the new imperative for creating and profiting from technology. Boston, Harvard Business School Press.

CSIS (2008). Briefing of the Working Group on the Health of the U.S. Space Industrial Base and the Impact of Export Controls, Center for Strategic & International Studies.

Dinerman, T. (2005). "Fixing ITAR: the saga continues." The Space Review, Retrieved November 13, 2009, from http://www.thespacereview.com/article/374/1.

Dinerman, T. (2008). "ITAR's failure." The Space Review, Retrieved November 13, 2009, from http://www.thespacereview.com/article/1086/1.

Foust, J. (2005). "One Nation, Over Regulated: Is ITAR Stalling the New Space Race?" Ad Astra **17**(3).

Futron Corporation (2009). State of the Satellite Industry Report, Satellite Industry Association.

Knes, M. (2010). "Coordinating Committee for Multilateral Export Controls and the Wassenaar Arangement." Reference for Business, Retrieved January 7, 2010, from http://www.referenceforbusiness.com/encyclopedia/Con-Cos/Coordinating-Committee-for-Multilateral-Export-Controls-and-the-Wassenaar-Arrangement.html.

Kusiolek, R. (2008). "ITAR: Balancing the Global Playing Field?", Retrieved November 13, 2009, from http://www.satellitetoday.com/via/features/23882.html.

NASA. (2007). "Chapter 5. International Traffic in Arms Regulations (ITAR)." NASA Export Control Program (NPR 2190.1), Retrieved July 7, 2010, from http://nodis3.gsfc.nasa.gov/.

National Space Policy (2006). U.S. National Space Policy.

NSSO (2008). Barriers to Entry and Sustainability in the U.S. Space Industry, National Security Space Office.

NSSO. (2010). "NSSO's Strategic Plan." National Security Space Office, Retrieved February 10, 2010, from http://www.acq.osd.mil/nsso/organization/organization.htm.

OUSD-ATL. (2009). Annual Industrial Capabilities Report to Congress, Office of Under Secretary of Defense, Acquisition, Technology & Logistics, Industrial Policy

Phillips, R. (1997). Innovation and Firm Performance in Australian Manufacturing. Canberra, Industry Commission, Staff Research Paper.

Rogers, M. (1998). The Definition and Measurement of Innovation. The Performance of Australian Enterprises: Innovation, Productivity and Profitability. Parkville, Victoria, Melbourne Institute of Applied Economic and Social Research.

Schumpeter, J. (1934). The Theory of Economic Development Boston, Harvard University Press.

Space Foundation (2008). ITAR and the U.S. Space Industry. Washington, DC, Space Foundation.

Space Politics. (2009). "Sherman's march towards ITAR reform." Space Politics Retrieved December, 2009, from http://www.spacepolitics.com/2009/04/01/shermans-march-towards-itar-reform/.

Taylor, A. (2007). Defense Industrial Base Assessment: U.S. Space Industry Final Report. Dayton, OH, Air Force Research Laboratory.

Tidd, J. (2001). "Innovation management in context: environment, organization and performance." International Journal of Management Reviews **3**(3): 169-183.

U.S. Congress (2009). International Traffic in Arms Regulations. 22. C. o. F. Regulations**:** 461-569.

U.S. House of Representatives. (1999, January 3, 1999). "U.S. National Security and Military/Commercial Concerns with the People's Republic of China." Retrieved August 13, 2009, from www.house.gov/coxreport/cont/gncont.html.

United Nations (1967). Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies.

Van Atta, R., M. Bittmann, P. Collopy, B. Hartfield, B. Harmon, M. Kaplan, N. Karvonides, M. Lippitz, J. Mandelbaum, M. Marks, M. Patterson, K. Sullivan. (2007). Export Controls and the U.S. Defense Industrial Base, Institute for Defense Analyses.

Wheatley, M. (2009). "ITAR restrictions hamper America's space industry." Latest Procurement News, Retrieved November 13, 2009, from http://www.procurementleaders.com/news/latestnews/itar-hamper-space-industry/.

REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 074-0188*

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From – To)*
16-09-2010	Master's Thesis	Jun 2009 – Aug 2010

4. TITLE AND SUBTITLE

Exploring the Effects of International Traffic in Arms Regulations Restrictions on Innovation in the U.S. Space Industrial Base

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Landry, Kalliroi L., Major, USAF

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(S)

Air Force Institute of Technology
Graduate School of Engineering and Management (AFIT/EN)
2950 Hobson Way
WPAFB OH 45433-7765

8. PERFORMING ORGANIZATION REPORT NUMBER

AFIT/GRD/ENV/10-S01

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

AFSPC/A8/9 Plans and Programs
150 Vandenberg St, Suite 1105
Peterson AFB, CO 80914-4020

10. SPONSOR/MONITOR'S ACRONYM(S)

AFSPC/A8/9

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

13. SUPPLEMENTARY NOTES

14. ABSTRACT

The International Traffic in Arms Regulations (ITAR) are used to protect United States (U.S.) military technologies. However, changes to ITAR export controls regarding space technologies have had a major impact to the U.S. space industry. The literature mentions a concern for the health of lower-tier firms because they are a major source of innovation, but there is no additional information considering the effects of ITAR on space innovation at those lower tiers. The purpose of this thesis was to explore the implications of continuing the current ITAR restrictions with regard to innovation in the space industry. This research used a three-part approach: Part I used personal interviews to explore perceptions from the space enterprise. Part II was a secondary analysis of previously collected data. Part III compared the results of Parts I and II to assess the relationship between ITAR and innovation in the space industry. The analysis shows there is no significant evidence that ITAR has a direct effect on space innovation. However, the industry may see some secondary negative effects on innovation. This thesis reveals a need to examine other second or third order effects of ITAR in economic and political environments to advise current ITAR reform efforts.

15. SUBJECT TERMS

ITAR, Export Control, Innovation, Space Industry

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
					Lt Col J. Robert Wirthlin (AFIT/ENV)
a. REPORT	b. ABSTRACT	c. THIS PAGE			**19b. TELEPHONE NUMBER** *(Include area code)*
U	U	U	UU	98	937-785-3636 ext.4650

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39-18

	Form Approved *OMB No. 074-0188*